REPORTS OF THE FINNISH ENVIRONMENT INSTITUTE 31 | 2015

24th Annual Report 2015

Convention on Long-range Transboundary Air Pollution

International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems

Sirpa Kleemola and Martin Forsius (eds.)

Finnish Environment Institute

REPORTS OF THE FINNISH ENVIRONMENT
INSTITUTE 31 | 2015

24th Annual Report 2015

Convention on Long-range Transboundary Air Pollution

**International Cooperative Programme
on Integrated Monitoring of Air Pollution
Effects on Ecosystems**

Sirpa Kleemola and Martin Forsius (eds.)

wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

Helsinki 2015

FINNISH ENVIRONMENT INSTITUTE

SYKE

REPORTS OF THE FINNISH ENVIRONMENT INSTITUTE 31 | 2015
Finnish Environment Institute

Layout: Pirjo Lehtovaara
Cover photo: Hubert Schulte-Bisping
A view from Berezinsky Biosphere Reserve in Belarus

The publication is also available in the Internet:
www.syke.fi/publications | helda.helsinki.fi/syke

Juvenes Print, Tampere 2015

ISBN 978-952-11-4524-7 (pbk.)
ISBN 978-952-11-4525-4 (PDF)
ISSN 1796-1718 (print)
ISSN 1796-1726 (online)

CONTENTS

ABBREVIATIONS

AMAP	Arctic Monitoring and Assessment Programme
ANC	Acid neutralising capacity
ALTER-Net	A Long-Term Biodiversity, Ecosystem and Awareness Research Network
CCE	Coordination Center for Effects
CL	Critical Load
CNTER	Carbon-nitrogen interactions in forest ecosystems
ECE	Economic Commission for Europe
EMEP	Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
EnvEurope	EU LIFE project "Environmental quality and pressures assessment across Europe; the LTER network as an integrated and shared system for ecosystem monitoring"
EU	European Union
EU LIFE	EU's financial instrument supporting environmental and nature conservation projects throughout the EU
ExpeER	Experimentation in Ecosystem Research
Horizon 2020	H2020, EU Research and Innovation programme
ICP	International Cooperative Programme
ICP Forests	International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
ICP IM	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
ICP Materials	International Cooperative Programme on Effects on Materials
ICP M&M	ICP Modelling and Mapping, International Cooperative Programme on Modelling and Mapping of Critical Loads and Levels and Air Pollution Effects, Risks and Trends
ICP Waters	International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes
ICP Vegetation	International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops
ILTER	International Long Term Ecological Research Network
IM	Integrated Monitoring
JEG	JEG DM, Joint Expert Group on Dynamic Modelling
LifeWatch	EU-infrastructure project, e-science and infrastructure for biodiversity data and observatories
LRTAP Convention	Convention on Long-range Transboundary Air Pollution
LTER-Europe	European Long-Term Ecosystem Research Network
LTER-Network	Long Term Ecological Research Network
NFP	National Focal Point
TF	Task Force
TF on Health	The Joint Task Force on the Health Aspects of Air Pollution
UNECE	United Nations Economic Commission for Europe
WGE	Working Group on Effects

Summary

Background and objectives of ICP IM

Integrated monitoring of ecosystems means physical, chemical and biological measurements over time of different ecosystem compartments simultaneously at the same location. In practice, monitoring is divided into a number of compartmental subprogrammes which are linked by the use of the same parameters (cross-media flux approach) and/or same or close stations (cause-effect approach).

The International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM, www.syke.fi/nature/icpim) is part of the Effects Monitoring Strategy under the Convention on Long-range Transboundary Air Pollution (LRTAP Convention). The main objectives of the ICP IM are:

- To monitor the biological, chemical and physical state of ecosystems (catchments/plots) over time in order to provide an explanation of changes in terms of causative environmental factors, including natural changes, air pollution and climate change, with the aim to provide a scientific basis for emission control.
- To develop and validate models for the simulation of ecosystem responses and use them (a) to estimate responses to actual or predicted changes in pollution stress, and (b) in concert with survey data to make regional assessments.
- To carry out biomonitoring to detect natural changes, in particular to assess effects of air pollutants and climate change.

The full implementation of the ICP IM will allow ecological effects of heavy metals, persistent organic substances and tropospheric ozone to be determined. A primary concern is the provision of scientific and statistically reliable data that can be used in modelling and decision making.

The ICP IM sites (mostly forested catchments) are located in undisturbed areas, such as natural parks or comparable areas. The ICP IM network presently covers forty-two sites from thirteen countries. The international Programme Centre is located at the Finnish Environment Institute in Helsinki. The present status of the monitoring activities is described in detail in Section 1 of this report.

A manual detailing the protocols for monitoring each of the necessary physical, chemical and biological parameters is applied throughout the programme (Manual for Integrated Monitoring 1998, and updated web version).

Assessment activities within the ICP IM

Assessment of data collected in the ICP IM framework is carried out at both national and international levels. Key tasks regarding international ICP IM data have been:

- Input-output and proton budgets
- Trend analysis of bulk and throughfall deposition and runoff water chemistry
- Assessment of responses using biological data
- Dynamic modelling and assessment of the effects of different emission/deposition scenarios, including confounding effects of climate change processes
- Assessment of concentrations, pools and fluxes of heavy metals

- Calculation of critical loads for sulphur and nitrogen compounds, and assessment of critical load exceedance, as well as links between critical load exceedance and empirical impact indicators.

Conclusions from international studies using ICP IM data

Input-output and proton budgets, C/N interactions

Ion mass budgets have proved to be useful for evaluating the importance of various biogeochemical processes that regulate the buffering properties in ecosystems. Long-term monitoring of mass balances and ion ratios in catchments/plots can also serve as an early warning system to identify the ecological effects of different anthropogenically derived pollutants, and to verify the effects of emission reductions.

The first results of input-output and proton budget calculations were presented in the 4th Annual Synoptic Report (ICP IM Programme Centre 1995) and the updated results regarding the effects of N deposition were presented in Forsius et al. (1996). Data from selected ICP IM sites were also included in European studies for evaluating soil organic horizon C/N-ratio as an indicator of nitrate leaching (Dise et al. 1998, MacDonald et al. 2002). Results regarding the calculation of fluxes and trends of S and N compounds were presented in a scientific paper prepared for the Acid Rain Conference, Japan, December 2000 (Forsius et al. 2001). A scientific paper regarding calculations of proton budgets was published in 2005 (Forsius et al. 2005).

The budget calculations showed that there was a large difference between the sites regarding the relative importance of the various processes involved in the transfer of acidity. These differences reflected both the gradients in deposition inputs and the differences in site characteristics. The proton budget calculations showed a clear relationship between the net acidifying effect of nitrogen processes and the amount of N deposition. When the deposition increases also N processes become increasingly important as net sources of acidity.

A critical deposition threshold of about 8–10 kg N ha^{-1} yr^{-1}, indicated by several previous assessments, was confirmed by the input-output calculations with the ICP IM data (Forsius et al. 2001). The output flux of nitrogen was strongly correlated with key ecosystem variables like N deposition, N concentration in organic matter and current year needles, and N flux in litterfall (Forsius et al. 1996). Soil organic horizon C/N-ratio seems to give a reasonable estimate of the annual export flux of N for European forested sites receiving throughfall deposition of N up to about 30 kg N ha^{-1} yr^{-1}. When stratifying data based on C/N ratios less than or equal to 25 and greater than 25, highly significant relationships were observed between N input and nitrate leached (Dise et al. 1998, MacDonald et al. 2002, Gundersen et al. 2006). Such statistical relationships from intensively studied sites can be efficiently used in conjugation with regional monitoring data (e.g. ICP Forests and ICP Waters data) in order to link process level data with regional-scale questions.

An assessment on changes in the retention and release of S and N compounds at the ICP IM sites was prepared for the 21st Annual Report (Vuorenmaa et al. 2012). Updated and revised data were included in the continuation of the work in the 22nd and 23rd Annual Reports (Vuorenmaa et al. 2013, 2014). The relationship between N deposition and organic N loss and the role of organic nitrogen in the total nitrogen output fluxes were derived in Vuorenmaa et al. (2013).

Sulphur budgets calculations indicated a net release of S from many ICP IM sites, indicating that the soils are releasing previously accumulated S. Similar results have been obtained in other recent European plot and catchment studies.

The reduction in deposition of S and N compounds at the ICP IM sites, caused by the "Protocol to Abate Acidification, Eutrophication and Ground-level Ozone" of the LRTAP Convention ("Gothenburg protocol"), was estimated for the year 2010 using transfer matrices and official emissions. Implementation of the protocol will further decrease the deposition of S and N at the ICP IM sites in western and north western parts of Europe, but in more eastern parts the decrease will be smaller (Forsius et al. 2001).

Results from the ICP IM sites were also summarised in an assessment report prepared by the Working Group on Effects of the LRTAP Convention (WGE) (Sliggers & Kakebeeke 2004, Working Group on Effects 2004).

ICP IM contributed to an assessment report on reactive nitrogen (Nr) of the WGE. This report was prepared for submission to the TF on Reactive Nitrogen and other bodies of the LRTAP Convention to show what relevant information has been collected by the ICP Programmes under the aegis of the WGE to allow a better understanding of N_r effects in the ECE region. The report contributed relevant information for the revision of the Gothenburg Protocol. A revised Gothenburg Protocol was successfully finalised in 2012.

It should also be recognized that there are important links between N deposition and the sequestration of C in the ecosystems (and thus direct links to climate change processes). These questions were studied in the CNTER-project in which data from both the ICP IM and EU/Intensive Monitoring sites were used (Gundersen et al. 2006). A summary report of the CNTER-results on C/N -interactions and nitrogen effects in European forest ecosystems was prepared for the WGE meeting 2007 (ECE/EB.AIR/WG.1/2007/10).

Trend analysis

Empirical evidence on the development of environmental effects is of central importance for the assessment of success of international emission reduction policy. First results from a trend analysis of monthly ICP IM data on bulk and throughfall deposition as well as runoff water chemistry were presented in Vuorenmaa (1997). ICP IM data on water chemistry were also used for a trend analysis carried out by the ICP Waters and results were presented in the Nine Year Report of that programme (Lükewille et al. 1997).

Calculations on the trends of N and S compounds, base cations and hydrogen ions were made for 22 ICP IM sites with available data across Europe (Forsius et al. 2001). The site-specific trends were calculated for deposition and runoff water fluxes using monthly data and non-parametric methods. Statistically significant downward trends of SO_4, NO_3 and NH_4 bulk deposition (fluxes or concentrations) were observed at 50% of the ICP IM sites. Sites with higher N deposition and lower C/N-ratios clearly showed higher N output fluxes, and the results were consistent with previous observations from European forested ecosystems. Decreasing SO_4 and base cation trends in runoff waters were commonly observed at the ICP IM sites. At some sites in the Nordic countries decreasing NO_3 and H^+ trends (increasing pH) were also observed. The results partly confirm the effective implementation of emission reduction policy in Europe. However, clear responses were not observed at all sites, showing that recovery at many sensitive sites can be slow and that the response at individual sites may vary greatly.

Data from ICP IM sites were also used in a study of the long-term changes and recovery at nine calibrated catchments in Norway, Sweden and Finland (Moldan et al. 2001, RECOVER: 2010 project). Runoff responses to the decreasing deposition trends were rapid and clear at the nine catchments. Trends at all catchments showed the same general picture as from small lakes in Scandinavia.

It was agreed at the ICP IM Task Force meeting in 2004 that a new trend analysis should be carried out. The preliminary results were presented in Kleemola (2005) and the updated results in the 15th Annual Report (Kleemola et al. 2006). Statistically significant decreases in SO_4 concentrations were observed at a majority of sites in both deposition and runoff/soil water quality. Increases in ANC (acid neutralising capacity) were also commonly observed. For NO_3 the situation was more complex, with fewer decreasing trends in deposition and even some increasing trends in runoff/soil water.

Results from several ICPs and EMEP were used in an assessment report on acidifying pollutants, arctic haze and acidification in the arctic region prepared for the Arctic Monitoring and Assessment Programme (AMAP, Forsius & Nyman 2006, www.amap.no). Sulphate concentrations in air generally showed decreasing trends since the 1990s. In contrast, levels of nitrate aerosol were increasing during the arctic haze season at two stations in the Canadian arctic and Alaska, indicating a decoupling between the trends in sulphur and nitrogen. Chemical monitoring data showed that lakes in the Euro-Arctic Barents region are showing regional scale recovery. Direct effects of sulphur dioxide emissions on trees, dwarf shrubs and epiphytic lichens were observed close to large smelter point sources.

Vuorenmaa et al. (2009) made a more recent trend evaluation using ICP IM data. These results confirmed the previously observed regional-scale decreasing trends of S in deposition and runoff/soil water. Acid-sensitive ICP IM sites in northern Europe also indicated recovery from acidification. The situation regarding N was quite different with only a few decreasing trends in deposition and both decreasing and increasing trends in runoff/soil water. Critical load calculations for Europe also indicate exceedances of the N critical loads over large areas. It was concluded that the N problem thus clearly requires continued attention as a European air pollution issue.

An assessment on changes in the retention and release of S and N compounds at the ICP IM sites was prepared for the 21st Annual Report (Vuorenmaa et al. 2012). Updated and revised data were included in the continuation of the work in the 22nd and 23rd Annual Reports. The role of organic nitrogen in mass balance budget was derived and trends of S and N in fluxes were analysed (Vuorenmaa et al. 2013, 2014).

Detected responses in biological data

The effect of pollutant deposition on natural vegetation, including both trees and understorey vegetation, is one of the central concerns in the impact assessment and prediction. The first assessment of vegetation monitoring data at ICP IM sites with regards to N and S deposition was carried out by Liu (1996). Vegetation monitoring was found useful in reflecting the effects of atmospheric deposition and soil water chemistry, especially regarding sulphur and nitrogen. The results suggested that plants respond to N deposition more directly than to S deposition with respect to vegetation indices.

De Zwart (1998) carried out an exploratory multivariate statistical gradient analysis of possible causes underlying the aspect of forest damage at ICP IM sites. These results suggested that coniferous defoliation, discolouration and lifespan of needles in the diverse phenomena of forest damage are for respectively 18%, 42% and 55% explained by the combined action of ozone and acidifying sulphur and nitrogen compounds in air.

As a separate exercise, the epiphytic lichen flora of 25 European ICP IM monitoring sites, all situated in areas remote from local air pollution sources, was statistically related to measured levels of SO_2 in air, NH_4^+, NO_3^- and SO_4^{2-} in precipitation, annual bulk precipitation, and annual average temperature (van Herk et al. 2003, de Zwart et al. 2003). It was concluded that long distance transport of nitrogen air pollution is important in determining the occurrence of acidophytic lichen species, and constitutes a threat to natural populations that is strongly underestimated so far.

In 2010, the Task Force meeting decided upon a new reporting format for biological data. The new format was based on primary raw data, and not aggregated mean values as before. All countries were encouraged to re-report old data in the new format. This was successful and as a result, the full potential of the biological data from the ICP Integrated Monitoring network could be utilised to raise and answer research questions that the old database could not.

The first study utilising the new database focussed on effects on forest floor vegetation from elevated nitrogen deposition (Dirnböck et al. 2014).

In many European countries airborne nitrogen coming from agriculture and fossil fuel burning exceeds critical thresholds and threatens the functioning of ecosystems. One effect is that high levels of nitrogen stimulate the growth of only a few plants which outcompete other, often rare species. As a consequence biodiversity declines. Though this is known to happen in natural and semi-natural grasslands, it has never been shown in forest ecosystems where management is a strong, mostly overriding determinant of biodiversity. Using the new database, long-term monitoring data from 28 Integrated Monitoring sites was utilised to analyse temporal trends in plant species cover and diversity (Dirnböck et al. 2014). At sites where nitrogen deposition exceeded the critical load, the cover of forest plant species preferring nutrient-poor soils (oligotrophic species) significantly decreased whereas plant species preferring nutrient-rich soils (eutrophic species) showed – though weak – an opposite trend. These results show that airborne nitrogen has changed the structure and composition of forest floor vegetation in Europe. Plant species diversity did not decrease significantly within the observed period but the majority of newly established species was found to be eutrophic. Hence it was hypothesized that without reducing nitrogen deposition below the critical load forest biodiversity will decline in the future.

Dynamic modelling and assessment of the effects of emission/deposition scenarios

In a policy-oriented framework, dynamic models are needed to explore the temporal aspect of ecosystem protection and recovery. The critical load concept, used for defining the environmental protection levels, does not reveal the time scales of recovery. Priority in the ICP IM work is given to site-specific modelling. The role of ICP IM is to provide detailed and consistent physical and chemical data and long time-series of observations for key sites against which model performance can be assessed and key uncertainties identified (see Jenkins et al. 2003). ICP IM participates also in the work of the Joint Expert Group on Dynamic Modelling (JEG) of the WGE.

Dynamic models have been developed and used for the emission/deposition and climate change scenario assessment at several selected ICP IM sites (e.g. Forsius et al. 1997, 1998a, 1998b, Posch et al. 1997, Jenkins et al. 2003, Futter et al. 2008, 2009). These models are flexible and can be adjusted for the assessment of alternative scenarios of policy importance. The modelling studies have shown that the recovery of soil and water quality of the ecosystems is determined by both the amount and the time of implementation of emission reductions. According to the models, the timing of emission reductions determines the state of recovery over a short time scale (up to 30 years). The quicker the target level of reductions is achieved, the more rapidly the surface water and soil status recover. For the long-term response (> 30 years), the magnitude of emission reductions is more important than the timing of the reduction.

The model simulations also indicate that N emission controls are very important to enable the maximum recovery in response to S emission reductions. Increased nitrogen leaching has the potential to not only offset the recovery predicted in response to S emission reductions but further to promote substantial deterioration in pH status of freshwaters and other N pollution problems in some areas of Europe.

Work has also been conducted to predict potential climate change impacts on air pollution related processes at the sites. The large EU-project Euro-limpacs (2004–2009) studied the global change impacts on freshwater ecosystems. The institutes involved in the project used data collected at ICP IM and ICP Waters sites as key datasets for the modelling, time-series and experimental work of the project. A modelling assessment on the global change impacts on acidification recovery was carried out in the project (Wright et al. 2006). The results showed that climate/global change induced changes may clearly have a large impact on future acidification recovery patterns, and need to be addressed if reliable future predictions are wanted (decadal time scale). However, the relative significance of the different scenarios was to a large extent determined by site-specific characteristics. For example, changes in sea-salt deposition were only important at coastal sites and changes in decomposition of organic matter at sites which are already nitrogen saturated.

In response to environmental concerns, the use of biomass energy has become an important mitigation strategy against climate change. A summary report on links between climate change and air pollution effects, based on results of the Euro-limpacs project, was prepared for the WGE meeting 2008 (ECE/EB.AIR/WG.1/2008/10). It was concluded that the increased use of forest harvest residues for biofuel production is predicted to have a significant negative influence on the base cation budgets causing re-acidification at the study catchments. Sustainable forestry management policies would need to consider the combined impact of air pollution and harvesting practices.

Dynamic vegetation modelling at ICP IM sites has been initiated with contributions from ICP M&M and ICP Forest.

Pools and fluxes of heavy metals

The work to assess concentrations, stores and fluxes of heavy metals at ICP IM sites is led by Sweden. Preliminary results on concentrations, fluxes and catchment retention were reported to the Working Group on Effects (document EB.AIR/WG.1/2001/10). The main findings on heavy metals budgets and critical loads at ICP IM sites were presented in Bringmark (2011). Input/output budgets and catchment retention for Cd, Pb and Hg in the years 1997–2011 were determined for 14 ICP IM catchments across Europe (Bringmark et al. 2013). Litterfall plus throughfall was taken as a measure of the total deposition of Pb and Hg (wet + dry) on the basis of evidence suggesting that, for these metals, internal circulation is negligible. The same is not true for Cd. Excluding a few sites with high discharge, between 74 and 94 % of the input, Pb was retained within the catchments; significant Cd retention was also observed. High losses of Pb (>1.4 $mg\,m^{-2}\,yr^{-1}$) and Cd (>0.15 $mg\,m^{-2}\,yr^{-1}$) were observed in two mountainous Central European sites with high water discharge. All other sites had outputs below or equal to 0.36 and 0.06 $mg\,m^{-2}\,yr^{-1}$, respectively, for the two metals. Almost complete retention of Hg, 86–99 % of input, was reported in the Swedish sites. These high levels of metal retention were maintained even in the face of recent dramatic reductions in pollutant loads.

In many national studies on ICP IM sites, detailed site-specific budget calculations of heavy metals (including mercury) have improved the scientific understanding of ecosystem processes, retention times and critical thresholds. ICP IM sites are also used for dynamic model development of these compounds.

Calculation of critical loads and their exceedance, relationships to effect indicators

Empirical impact indicators of acidification and eutrophication were determined from stream water chemistry and runoff observations at ICP IM catchments. The indicators were compared with exceedances of critical loads of acidification and eutrophication obtained with deposition estimates for the year 2000. Empirical impact indicators agreed well with the calculated exceedances. Annual mean fluxes and concentrations of acid neutralizing capacity (ANC) were negatively correlated with the exceedance of critical loads of acidification. Observed leaching of nitrogen was positively correlated with the exceedances of critical loads. A scientific paper on the key findings from these studies was published in 2013 (Holmberg et al. 2013), concluding that data from the ICP IM provide evidence of a connection between modelled critical loads and empirical monitoring results for acidification parameters and nutrient nitrogen.

Planned activities

- Maintenance and development of a central ICP IM database at the Programme Centre.
- Continued assessment of the long-term effects of air pollutants to support the implementation of emission reduction protocols, including:
  - Assessment of trends.
  - Calculation of ecosystem budgets, empirical deposition thresholds and site-specific critical loads.
  - Dynamic modelling and scenario assessment.
  - Comparison of calculated critical load exceedances with observed ecosystem effects.
- Calculation of pools and fluxes of heavy metals at selected sites.
- Assessment of cause-effect relationships for biological data, particularly vegetation.
- Coordination of work and cooperation with other ICPs, particularly regarding dynamic modelling (all ICPs), cause-effect relationships in terrestrial systems (ICP Forests, ICP Vegetation), and surface waters (ICP Waters).
- Participation in the development of the European LTER-network (Long Term Ecological Research network, www.lter-europe.net), and the related EU-infrastructure project LifeWatch (www.lifewatch.eu).
- Cooperation with other external organisations and programmes, particularly the International Long Term Ecological Research network (ILTER, www.ilternet.edu).
- Participation in projects with a global change perspective.

References

Bringmark, L. 2011. Report on updated heavy metal budgets and critical loads. In: Kleemola, S. & Forsius, M. (Eds.) 20th Annual Report 2011. ICP Integrated Monitoring. The Finnish Environment 18/2011, pp. 33–35. Finnish Environment Institute, Helsinki.

Bringmark, L., Lundin, L., Augustaitis, A., Beudert, B., Dieffenbach-Fries, H., Dirnböck, T., Grabner, M-T., Hutchins, M., Kram, P., Lyulko, I., Ruoho-Airola, T. & Vana, M. 2013. Trace Metal Budgets for Forested Catchments in Europe – Pb, Cd, Hg, Cu and Zn. Water, Air, and Soil Pollution, 224: 1502, 14p.

Dirnböck, T., Grandin, U., Bernhard-Römermann, M., Beudert, B., Canullo, R., Forsius, M., Grabner, M.-T., Holmberg, M., Kleemola, S., Lundin, L., Mirtl, M., Neumann, M., Pompei, E., Salemaa, M., Starlinger, F., Staszewski, T. & Uzięblo, A. K. 2014. Forest floor vegetation response to nitrogen deposition in Europe. Global Change Biology 20: 429–440. doi: 10.1111/gcb.12440

Dise, N.B, Matzner, E. & Forsius, M. 1998. Evaluation of organic horizon C:N ratio as an indicator of nitrate leaching in conifer forests across Europe. Environmental Pollution 102, S1: 453–456.

Forsius, M., Kleemola, S. & Vuorenmaa, J. 1996. Assessment of nitrogen processes at ICP IM sites. In: Kleemola, S. & Forsius, M. (Eds.) 5th Annual Report 1996. UNECE ICP Integrated Monitoring. The Finnish Environment 27, pp. 25–38. Finnish Environment Institute, Helsinki.

Forsius, M., Alveteg, M., Bak, J., Guardans, R., Holmberg, M., Jenkins, A., Johansson, M., Kleemola, S., Rankinen, K., Renshaw, M., Sverdrup, H. & Syri, S. 1997. Assessment of the Effects of the EU Acidification Strategy: Dynamic modelling on Integrated Monitoring sites. Finnish Environment Institute, Helsinki. 40 p.

Forsius, M., Alveteg, M., Jenkins, A., Johansson, M., Kleemola, S., Lükewille, A., Posch, M., Sverdrup, H. & Walse, C. 1998a. MAGIC, SAFE and SMART model applications at Integrated Monitoring Sites: Effects of emission reduction scenarios. Water, Air, and Soil Pollution 105: 21–30.

Forsius, M., Guardans, R., Jenkins, A., Lundin, L. & Nielsen, K.E. (Eds.) 1998b. Integrated Monitoring: Environmental assessment through model and empirical analysis – Final results from an EU/LIFE-project. The Finnish Environment 218. Finnish Environment Institute, Helsinki, 172 p.

Forsius, M., Kleemola, S., Vuorenmaa, J. & Syri, S. 2001. Fluxes and trends of nitrogen and sulphur compounds at Integrated Monitoring Sites in Europe. Water, Air, and Soil Pollution 130: 1641–1648.

Forsius, M., Kleemola, S. & Starr, M. 2005. Proton budgets for a monitoring network of European forested catchments: impacts of nitrogen and sulphur deposition. Ecological Indicators 5: 73–83.

Forsius, M. & Nyman, M. (Eds.) 2006. AMAP assessment 2006: acidifying pollutants, arctic haze, and acidification in the Arctic. Oslo, Arctic Monitoring and Assessment Program (AMAP). 112 p. www.amap.no.

Futter, M., Starr, M., Forsius, M. & Holmberg, M. 2008. Modelling long-term patterns of dissolved organic carbon concentrations in the surface waters of a boreal catchment. Hydrology and Earth System Sciences 12: 437–447.

Futter, M.N., Forsius, M., Holmberg, M. & Starr, M. 2009. A long-term simulation of the effects of acidic deposition and climate change on surface water dissolved organic carbon concentrations in a boreal catchment. Hydrology Research 40: 291–305.

Gundersen, P., Berg, B., Currie, W. S.,Dise, N.B., Emmett, B.A., Gauci, V., Holmberg, M., Kjønaas, O.J., Mol-Dijkstra, J., van der Salm, C., Schmidt, I.K., Tietema, A., Wessel, W.W., Vestgarden, L.S., Akselsson, C., De Vries, W., Forsius, M., Kros, H., Matzner, E., Moldan, F., Nadelhoffer, K. J., Nilsson, L.-O., Reinds, G.J., Rosengren, U., Stuanes, A.O. & Wright, R.F. 2006. Carbon-Nitrogen Interactions in Forest Ecosystems – Final Report. Forest & Landscape Working Papers no. 17–2006, Danish Centre for Forest, Landscape and Planning, KVL. 62 p.

van Herk, C. M., Mathijssen-Spiekman, E. A. M. & de Zwart, D. 2003. Long distance nitrogen air pollution effects on lichens in Europe. The Lichenologist 35 (4): 347–359.

Holmberg, M., Vuorenmaa, J., Posch, M., Forsius, M., Lundin, L., Kleemola, S., Augustaitis, A., Beudert, B., de Wit, H.A., Dirnböck, T., Evans, C.D., Frey. J., Grandin, U., Indriksone. I., Krám, P., Pompei, E., Schulte-Bisping, H., Srybnyn, A. & Vána, M. 2013. Relationship between critical load exceedances and empirical impact indicators at Integrated Monitoring sites across Europe. Ecological Indicators: 24:256–265.

ICP IM Programme Centre 1995. Assessment of nitrogen processes on ICP IM sites. In: 4th Annual Synoptic Report 1995, UNECE ICP Integrated Monitoring, pp. 19–61. Finnish Environment Agency, Helsinki.

Jenkins, A., Larssen, T., Moldan, F., Hruška, J., Krám, P. & Kleemola, S. 2003. Dynamic modelling at Integrated Monitoring sites – Model testing against observations and uncertainty. The Finnish Environment 636. Finnish Environment Institute, Helsinki. 37 p.

Kleemola, S. 2005. Trend assessment of bulk deposition, throughfall and runoff water chemistry at ICP IM sites. In: Kleemola, S. & Forsius, M. (Eds.) 14th Annual Report 2005. ICP Integrated Monitoring. The Finnish Environment 788, pp. 32–37. Finnish Environment Institute, Helsinki.

Kleemola, S. & Forsius, M. 2006. Trend assessment of bulk deposition, throughfall and runoff water/soil water chemistry at ICP IM sites. In: Kleemola, S. & Forsius, M. (Eds.) 15th Annual Report 2006. ICP Integrated Monitoring. The Finnish Environment 30/2006, pp. 22–48. Finnish Environment Institute, Helsinki.

Liu, Q. 1996. Vegetation monitoring in the ICP IM programme: Evaluation of data with regard to effects of N and S deposition. In: Kleemola, S. & Forsius, M. (Eds.) 5th Annual Report 1996. UNECE ICP Integrated Monitoring. The Finnish Environment 27, pp. 55–79. Finnish Environment Institute, Helsinki.

Lükewille, A., Jeffries, D., Johannessen, M., Raddum, G., Stoddard, J. & Traaen, T. 1997. The nine year report: Acidification of surface water in Europe and North America. Long-term developments (1980s and 1990s). Norwegian Institute for Water Research, Oslo. NIVA Report 3637–97.

MacDonald, J.A., Dise, N.B., Matzner, E., Armbruster, M., Gundersen, P. & Forsius, M. 2002. Nitrogen input together with ecosystem nitrogen enrichment predict nitrate leaching from European forests. Global Change Biology 8: 1028–1033.

Manual for Integrated Monitoring 1998. Finnish Environment Institute, Helsinki, Finland. Updated web version: www.syke.fi/nature/icpim > Manual for Integrated Monitoring

Moldan, F., Wright, R.F., Löfgren, S., Forsius, M., Ruoho-Airola, T. & Skjelkvåle, B.L. 2001. Long-term changes in acidification and recovery at nine calibrated catchments in Norway, Sweden and Finland. Hydrology and Earth System Sciences 5: 339–349.

Posch, M., Johansson, M. & Forsius, M. 1997. Critical loads and dynamic models. In: Kleemola, S. & Forsius, M. (Eds.) 6th Annual Report 1997. UN ECE ICP Integrated Monitoring. The Finnish Environment 116, pp. 13–23. Finnish Environment Institute, Helsinki.

Sliggers, J. & Kakebeeke, W. (Eds.) 2004. Clearing the Air: 25 years of the Convention on Long-range Transboundary Air Pollution. Geneva, United Nations Economic Commission for Europe.167 p.

de Vries, W., Forsius, M., Lorenz, M., Lundin, L., Haussman, T., Augustin, S., Ferretti, M., Kleemola, S. & Vel, E. 2002. Cause-effect relationships of Forest Ecosystems. Joint Report by ICP Forests and ICP Integrated Monitoring. Federal Research Centre for Forestry and Forest Products (BFH) & Finnish Environment Institute (SYKE). 46 p.

Vuorenmaa, J. 1997. Trend assessment of bulk and throughfall deposition and runoff water chemistry at ICP IM sites. In: Kleemola, S. & Forsius, M. (Eds.) 6th Annual Report 1997. UN ECE ICP Integrated Monitoring. The Finnish Environment 116, pp. 24–42. Finnish Environment Institute, Helsinki.

Vuorenmaa, J., Kleemola, S. & Forsius, M. 2009. Trend assessment of bulk deposition, throughfall and runoff water/soil water chemistry at ICP IM sites In: Kleemola, S. & Forsius, M. (Eds.) 18th Annual Report 2009. ICP Integrated Monitoring. The Finnish Environment 23/2009, pp. 36–63. Finnish Environment Institute, Helsinki.

Vuorenmaa, J. et al. 2012. Interim report: Sulphur and nitrogen input-output budgets at ICP Integrated Monitoring sites in Europe. In: Kleemola, S. & Forsius, M. (Eds.) 21st Annual Report 2012. ICP Integrated Monitoring. The Finnish Environment 28/2012, pp.23–34. Finnish Environment Institute, Helsinki.

Vuorenmaa, J. et al. 2013. Sulphur and nitrogen input-output budgets at ICP Integrated Monitoring sites in Europe. In: Kleemola, S. & Forsius, M. (Eds.) 22nd Annual Report 2013. ICP Integrated Monitoring. Reports of Finnish Environment Institute 25/2013, pp. 35–43, Helsinki.

Vuorenmaa, J. et al. 2014. Sulphur and nitrogen input-output budgets at ICP Integrated Monitoring sites in Europe in 1990-2012. In: Kleemola, S. & Forsius, M. (Eds.) 23rd Annual Report 2014. ICP Integrated Monitoring. Reports of Finnish Environment Institute 23/2014, pp. 28–35, Helsinki.

Working Group on Effects 2004. Integrated Monitoring of Ecosystems.In: Review and assessment of air pollution effects and their recorded trends. Report of the Working Group on Effects of the Convention on Long-range Transboundary Air Pollution, pp. 30–33. Geneva, United Nations Economic Commission for Europe.

Wright, R.F., Aherne, J., Bishop, K., Camarero, L., Cosby, B.J., Erlandsson, M., Evans, C.D., Forsius, M., Hardekopf, D., Helliwell, R., Hruška, J., Jenkins, A., Kopáček, J., Moldan, F., Posch, M. & Rogora, M. 2006. Modelling the effect of climate change on recovery of acidified freshwaters: Relative sensitivity of individual processes in the MAGIC model. Science of the Total Environment 365: 154–166.

de Zwart, D. 1998. Multivariate gradient analysis applied to relate chemical and biological observations. In: Kleemola, S. & Forsius, M. (Eds.) 7th Annual Report 1998. UN ECE ICP Integrated Monitoring. The Finnish Environment 217, pp. 15–29. Finnish Environment Institute, Helsinki.

de Zwart, D., van Herk, K.C.M. & Mathijssen-Spiekman, L.E.A. 2003. Long distance nitrogen air pollution effects on lichens in Europe. In: Kleemola, S. & Forsius, M. (Eds.) 12th Annual Report 2003. UN ECE ICP Integrated Monitoring. The Finnish Environment 637, pp. 32–37. Finnish Environment Institute, Helsinki.

1 ICP IM activities, monitoring sites and available data

1.1

Review of the ICP IM activities in 2014–2015

Meetings

- ICP IM Programme Manager Martin Forsius took part in the LIFE Platform Meeting 'Climate change – ecosystem services approach for adaptation and mitigation' in Norwich, England, 14–15 May 2014.
- The Chairman Lars Lundin represented the ICP IM programme at the 30th ICP Forests Task Force meeting in Athens, Greece, 29–30 May 2014.
- Lars Lundin and Martin Forsius participated in the joint meeting between the WGE Extended Bureau and the EMEP Steering Body, 17 September 2014 in Geneva, Switzerland.
- Lars Lundin and Martin Forsius represented ICP IM in the Working Group on Effects (WGE) 33rd meeting in Geneva, Switzerland, 17–19 September 2014.
- Martin Forsius took part in the ExpeER International Conference 2014, 'Experimentation in Ecosystem Research in a Changing World: Challenges and Opportunities' in Paris, France, 24–25 September 2014.
- Martin Forsius attended the TERENO International Conference 2014 'From observation to prediction in terrestrial systems' in Bonn, Germany, September 29th – October 2nd 2014.
- Jussi Vuorenmaa represented the ICP IM programme at the 30th Task Force meeting of ICP Waters in Grimstad, Norway, 14–16 October 2014.
- Martin Forsius represented ICP IM in the 22nd ILTER Annual Meeting on Chiloé Island, Chile, 4–8 December 2014.
- Martin Forsius participated in the AMAP Heads of Delegation Meeting in Copenhagen, Denmark, 4–5 February 2015.
- Lars Lundin represented the ICP IM programme in the Joint meeting of the EMEP Steering Body and the Extended Bureau of the Working Group on Effects in Geneva, Switzerland, 16–19 March 2015.
- Filip Moldan took part and represented ICP IM in the 25th CCE Workshop and 31st Task Force Meeting of the ICP M&M in Zagreb, Croatia, 20–23 April 2015.
- The twenty-third meeting of the Programme Task Force on ICP Integrated Monitoring was held in Minsk, Belarus on 7 May 2015. A one-day workshop on the assessment of ICP IM data was held prior to the Task Force meeting on 6 May.

Projects, data issues

After December 1st 2014 the National Focal Points (NFPs) reported their 2013 results to the ICP IM Programme Centre. The Programme Centre carried out standard check-up of the results and incorporated them into the IM database.

Scientific work in priority topics

- The Programme Centre prepared the ICP IM contribution to the Joint Report 2014 of the ICPs, Task Force on Health and Joint Expert group on Dynamic Modelling for the WGE (ECE/EB.AIR/WG.1/2014/3)
- Programme Centre prepared the contribution to the joint WGE trend report.
- Progress report on dynamic modelling and vegetation responses at ICP IM sites is included as a chapter in the present Annual Report 2015 (M. Holmberg et al.). A scientific report is planned for 2017.
- Progress report on heavy metal trends at ICP IM sites is included in the present Annual Report (S. Åkerblom & L. Lundin).
- Progress report on assessing long-term trends in ecosystem effects of sulphur and nitrogen at ICP IM sites (J. Vuorenmaa et al.) is included in this report.
- eLTER EU/H2020 research infrastructure project: relations to ICP IM activities (M. Forsius) is also presented in the present Annual Report.
- A scientific paper on mass balances for sulphur and nitrogen at ICP IM sites (J. Vuorenmaa et al.) is planned for 2015.
- ICP IM participates in a joint coordinated exercise on dynamic modelling together with other ICPs (Joint Expert Group on Dynamic Modelling, JEG DM). Priority in the ICP IM work is given to site-specific modelling activities and development/testing of new methodologies for assessing the connections between air pollution and climate change.

1.2

Activities and tasks planned for 2015–2017

Activities/tasks related to the programme's present objectives, carried out in close collaboration with other ICPs/ Task Forces

According to the workplan of the Working Group on Effects, ICP IM will produce the following reports:

2015: Finalization of ICP IM contribution to the WGE trend report
2015: A scientific paper on mass balances for sulphur and nitrogen at ICP IM sites
2016: Report on assessing long-term trends in ecosystem effects of sulphur and nitrogen
2016-2017: Report (2016) and scientific paper (2017) on dynamic response of vegetation changes in relation to nitrogen
2017: Report on heavy metal trends and budgets

Other activities

- Maintenance and development of central ICP IM database at the Programme Centre
- Arrangement of the 24th Task Force meeting together with ICP Waters (2016)
- Preparation of the 25th ICP IM Annual Report (2016)
- Preparation of the ICP IM contribution to assessment reports of the WGE
- Participation in meetings of the WGE, other ICPs and the JEG DM

Activities/tasks aimed at further development of the programme

- Participation in the development of the European LTER-network (Long Term Ecological Research network, www.lter-europe.net), the EU/H2020 eLTER-project, and the related EU-infrastructure project LifeWatch (www.lifewatch.eu)
- Participation in the activities of other external organisations, particularly the International Long Term Ecological Research Network (ILTER, www.ilternet.edu)

1.3

Published reports and articles 2014–2015

Evaluations of international ICP IM data and related publications

Dirnböck, T., Grandin, U., Bernhardt-Römermann, M., Beudert, B., Canullo, R., Forsius, M., Grabner, M.-T., Holmberg, M., Kleemola, S., Lundin, L., Mirtl, M., Neumann, M., Pompei, E., Salemaa, M., Starlinger, F., Staszewski, T., Uzieblo, A.K. 2014. Forest floor vegetation response to nitrogen deposition in Europe. Global Change Biology 20: 429–440.

Kleemola, S. & Forsius, M. (Eds.) 23rd Annual Report 2014. Convention on Long-range Transboundary Air Pollution, ICP Integrated Monitoring. Reports of Finnish Environment Institute 23/2014, Helsinki. 61 p. http://hdl.handle.net/10138/135815

Evaluations of national ICP IM data and publications of ICP IM representatives

Beudert, B., Bässler, C., Thorn, S., Noss, R., Schröder, B., Dieffenbach-Fries, H., Foullois, N. & Müller, J. 2015. Bark beetles increase biodiversity while maintaining drinking water quality. Conservation Letters.

Camino-Serrano, M., Gielen, B., Luyssaert, S., Ciais, P., Vicca, S., Guenet, B., De Vos, B., Cools, N., Ahrens, B., Arain, M.A., Borken, W.,Clarke, N., Clarkson, B., Cummins, T.,Don, A., Graf Pannatier, E.,Laudon, H.,Moore, T., Nieminen, T.M.,Nilsson, M.B., Peichl, M.,Schwendenmann, L.,Siemens, J. & Janssens, I. 2014. Linking variability in soil solution dissolved organic carbon to climate, soil type, and vegetation type. Global Biogeochemical Cycles 28(5): 497–509.

Fu, B. & Forsius, M. 2015. Ecosystem services modeling in contrasting landscapes (editorial). Landscape Ecology 30: 375–379.

Goutanis, G., Nikolaidis, N.P., Krám, P., Lamačová, A. 2014. Modeling the hydrologic response of Lysina catchment (Czech Republic) using the SWAT model. In: Liakopoulos A., Kungolos A., Christodoulatos C., Koutsopsyros (eds.) 12th International Conference on Protection and Restoration of the Environment Proceedings, Grafima Publ., Thessaloniki, Greece, 16–22.

Hartl-Meier, C., Zang, C., Büntgen, U., Esper, J., Rothe, A., Göttlein, A., Dirnböck, T., & Treydte, K. 2015. Uniform climate sensitivity in tree-ring stable isotopes across species and sites in a mid-latitude temperate forest. Tree Physiology, 35: 4–15.

Helliwell, R.C., Wright, R.F., Jackson-Blake, L.A., Ferrier, R.C., Aherne, J., Cosby, B.J., Evans, C.D., Forsius, M., Hruska, J., Jenkins, A., Kram, P., Kopáček, J., Majer, V., Moldan, F., Posch, M., Potts, J.M., Rogora, M., Schopp, W. 2014. Assessing recovery from acidification of European surface waters in the year 2010: Evaluation of projections made with the MAGIC model in 1995. Environmental Science and Technology 48: 13280–13288.

Hruška, J., Krám, P., Moldan, F., Oulehle, F., Evans, C., Wright, R.F., Cosby, B.J. 2014. Changes in soil DOC affect reconstructed history and projected future trends in surface water acidification. Water, Soil, and Air Pollution 225(7): ArtNo 2015, 13 p.

Jonard, M., Fürst, A., Verstraeten, A., Thimonier, A., Timmermann, V., Potocic, N., Waldner, P., Benham, S., Hansen, K., Merilä, P., Quentin Ponette, Q., de la Cruz, A.C., Roskams, P., Nicolas, M., Croisé, L., Ingerslev, M., Matteucci, G., Decinti, B., Bascietto, M. & Rautio, P. 2015. Tree mineral nutrition is deteriorating in Europe. Global Change Biology 21(1): 418–430.

Kobler, J., Jandl, R., Mirtl, M., Dirnböck, T., & Schindlbacher, A. 2015. Effects of stand patchiness due to windthrow and bark beetle abatement measures on soil CO2 efflux and net ecosystem productivity of a managed temperate mountain forest. European Journal of Forest Research 134:683–692.

Krám, P., Farkaš, J., Pereponova, A., Nwaogu, C., Štědrá, V., Hruška, J. 2014. Bedrock weathering and stream water chemistry in felsic and ultramafic forest catchments. Procedia Earth and Planetary Sciences 10: 52–55.

Krám, P., Myška, O., Hruška, J., Čuřík, J., Veselovský, F., Navrátil, T., Rohovec, J. 2014. Streamwater chemistry at Lysina (CZ07). In: de Wit H., Bente M., Wathne B.M., Hruška J. (eds.) ICP Waters Report 117/2014, Proceedings of the 29th Task Force meeting of the ICP Waters Programme in Český Krumlov, Czech Republic, October 1–3, 2013, 7–10. Norwegian Institute for Water Research Report SNO 6643–2014, Oslo.

Lamačová, A., Hruška, J., Krám, P., Stuchlík, E., Farda, A., Chuman, T., Fottová, D. 2014. Runoff trends analysis and future projections of hydrologic patterns in small forested catchments. Soil and Water Research 9: 169–181.

Löfgren, S., Grandin, U. & Stendera, S. 2014. Long-term effects on nitrogen and benthic fauna of extreme weather events: Examples from two Swedish headwater streams. Ambio 43, 58-76.

Löfgren, S. (ed.) 2015. Integrated monitoring of the environmental status in Swedish forest ecosystems – IM. Annual report for 2013. Swedish University of Agricultural Sciences. Department of Aquatic Sciences and Assessment, Report 2015:8. Uppsala Sweden. 32 pp, 22 appendices. (in Swedish with English summary)

Menon, M., Rousseva, S., Nikolaidis, N.P., van Gaans, P., Panagos, P., de Souza, D.M., Ragnarsdottir, K.V., Lair, G.J., Weng, L., Bloem, J., Kram, P., Novak, M., Davidsdottir, B., Gisladottir, G., Robinson, D.A., Reynolds, B., White, T., Lundin, L., Zhang, B., Duffy, C., Bernasconi, S.M., de Ruiter, P., Blum, W.E.H., Banwart, S.A. 2014. SoilTrEC: A global initiative on critical zone research and integration. Environmental Science and Pollution Research 21: 3191–3195.

Napa, Ü., Kabral, N., Liiv, S., Asi, E., Timmusk, T. & Frey, J. 2015. Current and historical patterns of heavy metals pollution in Estonia as reflected in natural media of different ages: ICP Vegetation, ICP Forests and ICP Integrated Monitoring data. Ecological Indicators, Vol. 52, pp. 31-39.

Navrátil, T., Shanley J., Rohovec, J., Hojdová, M., Penížek, V., Buchtová, J. 2014. Distribution and pools of mercury in Czech forest soils. Water, Air, and Soil Pollution 225(3): ArtNo 1829,17 p.

Oulehle, F., Fottová, D., Hruška, J., Krám, P., Štěpánová, M., Váňa, M. 2014. Long-term hydrochemical monitoring in the Anenský Potok catchment as a part of the GEOMON network. In: Váňa, M., Dvorská, A. et al. (eds.) Košetice Observatory – 25 Years, Czech Hydrometeorological Institute, Prague, 87–93. ISBN 978-80-87577-40-0.

Regelink, I.C., Stoof, C.R., Rousseva, S., Weng,,L., Lair, G.J., Kram, P., Nikolaidis, N.P., Kercheva, M., Banwart, S., Comans, R.N.J. 2015. Linkages between aggregate formation, porosity and soil chemical properties. Geoderma 247–248: 24–37.

Rask, M., Arvola, L., Forsius, M. & Vuorenmaa, J. 2014. Report on national ICP IM activities in Finland - a summary of main results from the Valkea-Kotinen Integrated Monitoring Catchment during 1990–2009. In: Kleemola & S. Forsius, M. (eds.). 23rd Annual Report 2014. ICP Integrated Monitoring. Reports of the Finnish Environment Institute 23/2014, pp. 40–42.

Ruoho-Airola, T., Anttila, P., Hakola, H., Ryyppö, T. & Tuovinen, J.-P. 2015. Trends in the bulk deposition and atmospheric concentration of air pollutants in the Finnish Integrated Monitoring catchment Pallas during 1992–2012. Boreal Environment Research 20: 553–569.

Temnerud, J., Andersson, L., Arheimer, B., Bishop, K., Bringmark, L., Lundin, L., Löfgren, S. & Moldan, F. 2014.The CLEO-database: Nine forested headwater streams in Sweden, 1977–2009. http://www.slu.se/cleo/data

Ukonmaanaho, L., Starr, M., Lindroos, J.-A. & Nieminen, T.M. 2014. Long-term changes in acidity and DOC in throughfall and soil water in Finnish forests. Environmental Monitoring and Assessment 2014: 186: 7733–7752.

Waldner, Peter et al. (36 authors) 2014. Detection of temporal trends in atmospheric deposition of inorganic nitrogen and sulphate to forests in Europe. Atmospheric Environment 95: 363–374.

Váňa, M., Dvorská, A. , et al. 2014. Košetice Observatory – 25 Years, Czech Hydrometeorological Institute, Prague. 93 p. ISBN 978-80-87577-40-0.

Veresoglou, S.D., Peñuelas, J., Fischer, R., Rautio, P., Sardans, J., Merilä, P., Tabakovic-Tosic, M. & Rillig, M.C. 2014. Exploring continental-scale stand health – N:P ratio relationships for European forests. New Phytologist 202(2): 422–430.
Waldner, Peter et al. (36 authors) 2014. Detection of temporal trends in atmospheric deposition of inorganic nitrogen and sulphate to forests in Europe. Atmospheric Environment 95: 363–374.
Yu, X., Lamačová, A., Duffy, C., Krám, P., Hruška, J., White, T., Bhatt, G. 2015. Modeling long term water yield effects of forest management in a Norway spruce forest. Hydrological Sciences Journal 60: 174–191.

1.4

Monitoring sites and data

The following countries have continued data submission to the ICP IM data base during the period 2010–2014: Austria, Belarus, the Czech Republic, Estonia, Finland, Germany, Italy, Latvia, Lithuania, Norway, the Russian Federation, Spain, Sweden, and Ukraine. Ireland re-established a site in 2012 and will report data later this year and Switzerland will include a new site in 2015. Poland has indicated interest to include one or more sites to the network. The number of sites with on-going data submission for at least part of the data years 2009–2013 is forty-two from thirteen countries. Sites from Canada and United Kingdom only contain older data.

An overview of the data reported internationally to the ICP IM database is given in Table 1.1. Additional earlier reported data are available from sites outside those presented in Table 1.1. and Fig. 1.1. Locations of the ICP IM monitoring sites are shown in Fig. 1.1.

Table 1.1. Internationally reported data from ICP IM sites (- subprogramme not possible to carry out, * or forest health parameters in former Forest stands/Trees).

AREA	SUBPROGRAMME																							
	AM	AC	PC	MC	TF	SF	SC	SW	GW	RW	LC	FC	LF	RB	LB	FD*	VG	BI	VS	EP	AL	MB	BB	BV
	meteorology	air chemistry	precipitation chemistry	moss chemistry	throughfall	stemflow	soil chemistry	soil water chemistry	groundwater chemistry	runoff water chemistry	lake water chemistry	foliage chemistry	litterfall	hydrobiology of streams	hydrobiology of lakes	forest damage	vegetation	bioelements	vegetation structure	trunk epiphytes	aerial green algae	microbial decomposition	bird inventory	vegetation inventory
AT01	95-12	95-12	93-12		93-12	99-04		93-12		95-12	-	92-11	93-12				93			93-98				
BY02	89-14	89-14	89-14				95-98			95-14														
CZ01	89-13	89-13	89-13	89	89-13			07-13	08-13	89-13	-			07	-									
CZ02	67-14	93-96	90-13		91-13		93	90-13	89-13	89-13	91-13	94	08	07	11			94			14		10	
DE01	90-13	90-13	90-13	90	90-13	90-05	90-11	90-13	88-13	90-13	-	90-13	90-12		-	90-13	90-08		00	92-95		94-13	91-02	90-95
DE02	67-13	98-13	98-13		98-13	04-13	04-10	98-13	98-13		98-13	06-13	04-13				04-06							
EE01	95-13	94-13	94-13	94-10	94-13	94-13	94-10	94-13	95-96	-	-	94-13	94-13	-	-	94-13	94-97			94-04		94-13		94
EE02	94-13	98-13	94-13	94-12	94-13	94-13	94-10	95-13	95-01	94-13	96	94-13	94-13			96-13	96-12	12		94-12	94-12	96-13	98	
ES02	08-11	08-11	07-12		07-12	08-11	10	07-12		07-12		08-12	08-11			07-12	07		07					
FI01	88-14	94-13	88-13	88-96	89-12	89-99	88-89	89-01		88-13	87-13	88-01	90-97		90-93	88-91	88-09			88-97		90	87-89	87
FI03	88-14	93-00	88-13	89-96	89-12	89-99	88	89-01		88-13	87-13	88-01	90-97		90	88-91	90-09			90-97		90-91	87-89	
FI04	88-14	89-13	88-13	89-96	89-10	89-97	89	89-01		88-05	86-12	89-01	90-97			89-91	89-09			89-98		90-91	87-89	
FI05	88-14		88-13	91-96	89-97	89-97	88	89-96		89-13	87-13	88-01	90-97			88-91	89-09			89-97		90-91	88-89	
IT01	93-13	93-13	93-14		93-13	93-13	93-11	93-13		00-13	-	93-10	00	-	-	92-13	09		05-09	92		93-11		
IT02	77-13	93	93-14		93-13	93-13	93-10	93-13		-	-	93-01	00	-	-	92-13				92		93-11		
IT03	92-08	93-11	92-11		94-11	94-00	93-95	95-07		02-11	-	93-05	94	-	-	93-09	95-09		99-09	92				
IT05	97-08	97-11	97-11		97-11	97-11	95	02-08		-	-	97-05		-	-	97-09	09		99-09					
IT06	99-08	97-11	97-11		97-11	97-11	95			-	-	97-05		-	-	97-09	09		99-09					
IT07	97-08	97-11	97-11		97-09	97-00	95			98	-	97-05		-	-	97-09	09		99-09					
IT09	97-08	97-11	97-11		97-11	97-99	95	02-08		97-11	-	97-05		-	-	97-09	09		99-09					
IT10	97-08	00-11	97-11		97-11		95	05-07		-	-	97-05		-	-	97-09	09		99-09					
IT11		97-11	97-11		97-11		95			-	-	97-05		-	-	97-09	09		99-09					
IT12	97-01	97-11	97-11		97-11	97-00	95			-	-	97-05		-	-	97-09	09		99-09					
IT13	97-08	97-11	09-11		09-11		95			-	-	97-05		-	-	97-09			99-08					
LT01	93-11	93-12	93-13	93-10	93-13		93-05	94-12	93-12	93-12		06-13	99-13	12		00-13	93-13		02	93-13	93-13			93
LT03	95-09	95-12	95-13	06-10	95-13		94-05	95-12	95-12	95-12		06-13	99-13	95-12		00-13	94-13		02	94-13	94-13			94
LV01	93-08	93-09	93-09	94-98	94-09	94-09	94-03	94-09	94-07	93-09	-	94-08	94-08	95-07	-	94-08	94-06			94-06	01-08	96-98		
LV02	93-08	94-09	93-09	94-98	94-09	94-09	94-03	94-09	94-08	93-09	93-98	94-08	94-08	95-07	95-98	94-08	94-06		01	94-06	01-08	96-98		
NO01	87-13	87-13	87-13	92	89-13		86	89-09	87-88	87-13	-	86			-	91-03	86			86				
NO02	87-91	87-13	87-13	88	89-11		89	89-09		87-13	-	89			-	92-03	89							
NO03			98-13							87-13														
RU03	89-94	89-13	89-98																					
RU04	89-06	89-13	89-98	90										93-99		93-13	93-02			93		94-96		
RU12	93-94	93-13	93-94																					
RU13	93	93-94	93													09-13								
RU14	94	94-12	94-98																					
RU16				89-90			89	89	89						93-99	93-13	91-94			89-94	93	94-95		91
SE04	87-13	88-13	87-13	95	87-13		95	87-13	79-13	87-13	-	99-13	96-12		-	97-01	95-13	91-10	91-10	96-11	92-12	95-13		
SE14	96-13	96-13	96-13	95	96-13			95-13	96-13	96-13	-	99-13	95-13		-	97-01	82-13	96-11	06-11	97-12	97-13	95-13		
SE15	97-13	96-13	96-13		96-13		97	95-13	97-13	96-13	-	97-13	95-13		-	98-01	96-13	98-13	98-13	98-13	97-13	95-13		
SE16	99-13	99-13	99-13		99-13			00-13	00-13	99-13		99-13	00-13			00-01	99-13	99-09	99-09	00-10	00-13	00-13		
XX01	12-13	12-13																						

Figure 1.1. Geographical location of ICP IM sites.

Site with on-going data submission
Site re-established in 2012
Site with earlier data only

1.5

National Focal Points (NFPs) and contact persons for ICP IM sites

AT/ Austria
NFP: Johannes Kobler and
Thomas Dirnböck
Environment Agency Austria
Spittelauer Lände 5
A-1090 Vienna
AUSTRIA
e-mail: johannes.kobler@umweltbundesamt.at
thomas.dirnboeck@umweltbundesamt.at

BY/ Belarus
NFP: Anatoly Srybny
Berezinsky Biosphere Reserve
P.O. Domzheritzy
Lepel District
Vitebskaya oblast, 211188
BELARUS
e-mail: srybny@vitb.pogoda.by

CZ/ Czech Republic
NFP and contact for site CZ01: Milan Váňa
Czech Hydrometeorological Institute
Observatory Košetice
CZ-394 22 Košetice
CZECH REPUBLIC
e-mail: vanam@chmi.cz

Contact for site CZ02: Pavel Krám
Czech Geological Survey
Department of Geochemistry
Klarov 3
CZ-118 21 Prague 1
CZECH REPUBLIC
e-mail: pavel.kram@geology.cz

DE/ Germany
NFP:
Helga Dieffenbach-Fries
Federal Environment Agency
Paul-Ehrlich-Straße 29
D-63225 Langen
GERMANY
e-mail: helga.fries@uba.de

Contact for site DE01: Burkhard Beudert
Nationalparkverwaltung Bayerischer Wald
Sachgebiet Forschung und Dokumentation
Integriertes Ökosystemmonitoring
Freyunger Straße 2
D-94481 Grafenau
GERMANY
e-mail: burkhard.beudert@npv-bw.bayern.de

Contact for site DE02: Hubert Schulte-Bisping
Büsgen-Institute
Georg August University of Göttingen
Büsgenweg 2
D-37077 Göttingen
GERMANY
e-mail: hschult1@gwdg.de

EE/ Estonia
NFP: Reet Talkop
Analysis and Planning Department
Ministry of the Environment
Narva mnt 7A-505
15172 Tallinn
ESTONIA
e-mail: reet.talkop@envir.ee

ES/ Spain
NFP: Jesús Miguel Santamaría
Laboratorio Integrado de Calidad Ambiental
LICA
Departamento de Química y Edafología
Universidad de Navarra
Irunlarrea 1, 31008 Pamplona
SPAIN
e-mail: chusmi@unav.es

FI/ Finland
Contact persons:
Sirpa Kleemola and Jussi Vuorenmaa
Finnish Environment Institute, SYKE
P.O. Box 140
FI-00251 Helsinki
FINLAND
e-mail: sirpa.kleemola@ymparisto.fi
jussi.vuorenmaa@ymparisto.fi

IE/Ireland
NFP: Thomas Cummins
University College Dublin
UCD School of Agriculture and Food Science
Belfield, Dublin 4
IRELAND
e-mail: thomas.cummins@ucd.ie

IT/ Italy
NFP:
Laura Canini and Angela Farina
National Forest Service (Div. VI)
CONECOFOR
Via Carducci 5
I-00187 Rome
ITALY
e-mail: l.canini@corpoforestale.it and
a.farina@corpoforestale.it

Contact for Alpine sites IT01, IT02:
Stefano Minerbi
Ufficio Servizi Generali Forestari
Via Brennero 6
I-39100 Bolzano
ITALY
e-mail: stefano.minerbi@provinz.bz.it

LT/ Lithuania
NFP: Gediminas Liutkevičius and
Gintaras Matiukas
Activity Planning and Public Information Division
Environmental Protection Agency
Juozapavičiaus st. 9
LT-09311 Vilnius
LITHUANIA
e-mail: g.liutkevicius@aaa.am.lt g.matiukas@aaa.am.lt

Contact for sites LT01, LT03:
Algirdas Augustaitis
Forest Monitoring Laboratory
Aleksandras Stulginskis University
Studentu 13
Kaunas distr.
LT-53362
LITHUANIA
e-mail: algirdas.augustaitis@asu.lt

LV/ Latvia
NFP: Iveta Indriksone
State Ltd Latvian Environment, Geology and
Meteorology Centre
Monitoring Department
Maskavas Str. 165
LV-1019 Riga
LATVIA
e-mail: epoc@lvgmc.lv

NO/ Norway
NFP: Heleen de Wit
Norwegian Institute for Water Research
NIVA
Gaustadalléen 21
NO- 0349 Oslo
NORWAY
e-mail: heleen.de.wit@niva.no

RU/ Russia
NFP: Anna Koukhta
Institute of Global Climate and Ecology
Glebovskaya str. 20 B
107258 Moscow
RUSSIA
e-mail: anna_koukhta@mail.ru

SE/ Sweden
NFP: Lars Lundin
Swedish University of Agricultural Sciences, SLU
Department of Aquatic Sciences and Assessment
P.O. Box 7050
SE-75007 Uppsala
SWEDEN
e-mail: lars.lundin@slu.se

Contact for site XX01, Karadag/Crimea:
Vladimir Lapchenko
Karadag Nature Reserve
Kurortnoe
Science st. 24
Feodosia
Crimea
e-mail: ozon.karadag@gmail.com

2 Progress report on dynamic vegetation modelling at ICP IM sites

Maria Holmberg [1] and Thomas Dirnböck [2]

[1] *Finnish Environment Institute (SYKE). P.O. Box 140, FI-00251 Helsinki, Finland*
[2] *Department for Ecosystem Research and Monitoring, Environment Agency Austria, Spittelauer Lände 5, A-1090 Vienna, Austria*

2.1 Introduction

The continuing high levels of air-borne nitrogen have an impact on natural ecosystems that are facing the simultaneous pressure of climate warming. The monitoring activities at the sites of the ICP IM and ICP Forest programmes produce high quality data that is valuable for identifying ecosystem responses. Our aim is to utilize the monitoring data from selected ICP IM and ICP Forest sites in a dynamic modelling study to evaluate future vegetation responses to future nitrogen deposition. This progress report briefly describes the methods and sites. The VSD+ model has been applied to simulate soil chemistry at ten sites in four countries (Austria, Italy, Poland and Finland). The next steps include application and calibration at further sites and, after the soil chemistry simulations are satisfactory at all sites, the vegetation responses will be estimated with the PROPS model. The impact on biodiversity is evaluated using the habitat suitability index HS (Posch et al. 2014).

2.2 Methods and Models

The VSD+PROPS model is used to generate plant species occurrence probabilities as a function of soil chemistry and climatic variables (Reinds et al. 2014). To assess the impact of N deposition on soil chemical status, the VSD+ dynamic soil chemistry model is used to simulate the soil C/N and pH (VSD+ version 5.2 of 1.5.2014; CCE, 2015). VSD+ is a single-layer dynamic soil chemistry model which simulates cation exchange and C and N dynamics (Bonten et al. 2012). It has been developed based on the VSD model (Posch & Reinds 2009, Reinds et al. 2009), which was designed to assess regional and national scale soil acidification. VSD+ includes calculation of the C and N balance. VSD+ calculates changes in soil organic matter contents using the RothC-26.3 model (Coleman & Jenkinson 2005). It includes five pools of soil organic carbon. The turnover rates for the pools are modified from reference turnover rates by accounting for temperature, moisture and soil cover. The model also includes N uptake, nitrification, denitrification and N leaching (Reinds et al. 2014).

The MetHyd model (version 1.5.1 of 21.11.2013) is used as a pre-processor for preparing meteorological and hydrological input to VSD+. The GrowUp model (version 1.3.2 of 1.11.2013) is used to calculate time series of forest growth and nitrogen and base cation uptake by vegetation used as input to VSD+.

The vegetation response to changing N deposition, soil C/N and pH is estimated with the PROPS model and its extended database (Reinds et al. 2014). PROPS estimates the occurrence probability of plant species as a function of soil chemistry and climate. As a measure of species diversity, the habitat suitability index is used (Rowe et al. 2009). The habitat suitability index is defined as the arithmetic mean of the normalised probabilities of occurrence of the species of interest (Posch et al. 2014).

$$HS = \frac{1}{n} \sum_{j=1}^{n} \frac{p_j}{p_{j},\, max}$$

n	number of species
p_j	occurrence probability of species j
$p_{j,\, max}$	the maximum occurrence probability of species j

Supporting information on natural habitat suitability is obtained from the BERN model (Schlütow et al. 2010).

2.3
Sites

A selected set of sites (Table 2.1.) with data on vegetation and soil properties as well as observations of soil water or runoff chemistry has been chosen for the dynamic model application. The sites are located from south N41° to north N63° and from west W09° to east E30°, including Mediterranean, Atlantic, temperate and boreal sites. The sites represent varying current climate conditions with annual average air temperature (from 3.1 °C to 12.0 °C, and average annual sum of precipitation from 620 mm to 1 770 mm (Fig. 2.1.a). The soils differ with respect to soil solution pH from 3.5 to 8.0 and soil C/N ratio from 12 to 31 (Fig. 2.1.b).

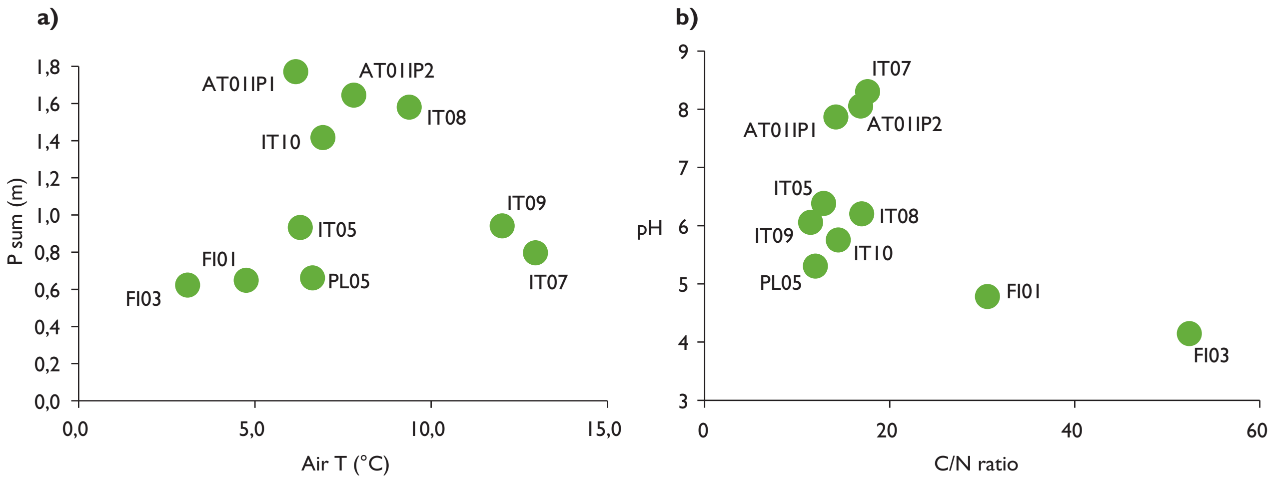


Figure 2.1.
a) Annual sum of precipitation (P, m) versus annual average air temperature (T, °C) at the sites. Observed values for 1999-2010 (IT), 2001 – 2014 (FI) and simulated with MetHyd (AT, PL).
b) Soil pH versus carbon to nitrogen ratio (C/N). Observed values for 1999 (pH IT05), 2004 (pH and C/N AT01), and 2006 (pH and C/N all other sites).

Table 2.1. Provisional list of ICP IM sites included in dynamic modelling study.

Country	Site Code	Site	Latitude	Longitude	EUNIS	Predominant vegetation
Austria	AT01	Zöbelboden	N47°50'	E14°26'	G3.1, G4	Spruce (*Picea abies*), Beech (*Fagus sylvatica*)
Czech Republic	CZ01	Anenske Povodi	N49° 35'	E15°05'	G1, G3.1	Alder (*Alnus*), Spruce (*Picea abies*)
	CZ02	Lysina	N50° 03'	E12° 40'	G3.1	Spruce (*Picea abies*)
Germany	DE01	Forellenbach	N48°56'	E13°25'	G1, G3.1	Beech (*Fagus sylvatica*), Spruce (*Picea abies*)
	DE02	Neuglobsow	N53° 08'	E13° 02'	G4	Beech (*Fagus sylvatica*) and pine (*Pinus sylvestris*)
	DEa					
	DEb					
Finland	FI01	Valkea-Kotinen	N61°14'	E25°03'	G3.A, G4.2	Spruce (*Picea abies*), Pine (*Pinus sylvestris*), Birch (*Betula* spp.)
	FI03	Hietajärvi	N63°09'	E30°40'	G3.A, G4.2	Spruce (*Picea abies*), Pine (*Pinus sylvestris*), Birch (*Betula* spp.)
Ireland	IE01	Brackloon Wood	N53° 46'	W09° 33'		Oak (*Quercus petraea*)
Italy	IT05	Selvapiana	N41°50'	E13°35'	G1.6	Beech (*Fagus sylvatica*)
	IT07	Carrega	N44°43'	E10°12'	G1.7	Oak (*Quercus petraea, pubescens*)
	IT08	Brasimone	N44°06'	E11°07'	G1.6	Beech (*Fagus sylvatica*)
	IT09	Monte Rufeno	N42°49'	E11°54'	G1.7	Oak (*Quercus cerris*)
	IT10	Val Masino	N46°14'	E09°33'	G4.6	Spruce (*Picea abies*)
Poland	PL05	Puszcza Borecka	N54°07'	E23°02'	G1.A1	Lime (*Tilia cordata*), Hornbeam (*Carpinus betulus*)
	SNP	Słowiński National Park			G3.4	Pine (*Pinus sylvestris*)
	TNP	Tatrzański National Park			G3.1	Fir (*Abies* spp.) Spruce (*Picea* spp.)
Sweden	SE04	Gårdsjön	N58° 03'	E12° 01'	G1, G3.1	Birch (*Betula*), Spruce (*Picea abies*)
	SE14	Aneboda	N57° 07'	E14° 32'	G3.1	Mixed Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*)
	SE15	Kindla	N59° 45'	E14° 54'	G3.A	Norway spruce (*Picea abies*)
	SE16	Gammtratten	N63°51'	E18°06'	G3.A	Norway spruce (*Picea abies*) and pine (*Pinus sylvestris*)

2.4
Deposition historic and future scenarios

Air pollutant emissions of sulphur (S) have declined since 1990, which is reflected in declining S deposition at all sites. The nitrogen (N) depositions, however, do not show a similar decline as those of S, because the N emissions have declined slightly but then stabilized at many sites (Fig. 2.2.). The historic deposition is based on older EMEP-model versions (Schöpp et al. 2003), while the deposition values for 2005, 2010, 2020 and 2030 are based on the latest EMEP model version (Simpson et al. 2012), using the current legislation scenario (CLE) with revised Gothenburg Protocol emissions.

The maximum levels of S and N deposition the sites were exposed to in the 1980s range from 0.04 and 0.03 eq m^{-2} yr^{-1} to 0.62 and 0.67 eq m^{-2} yr^{-1}, respectively (Fig. 2.3.).

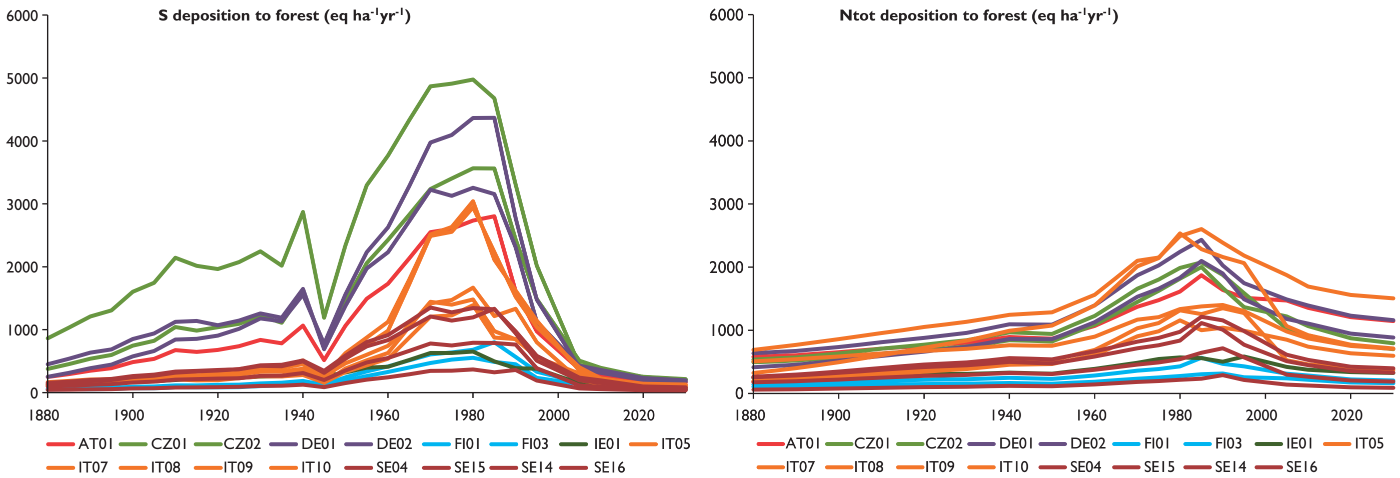


Figure 2.2. Historical and future deposition of S and total N (NO_3 + NH_4).

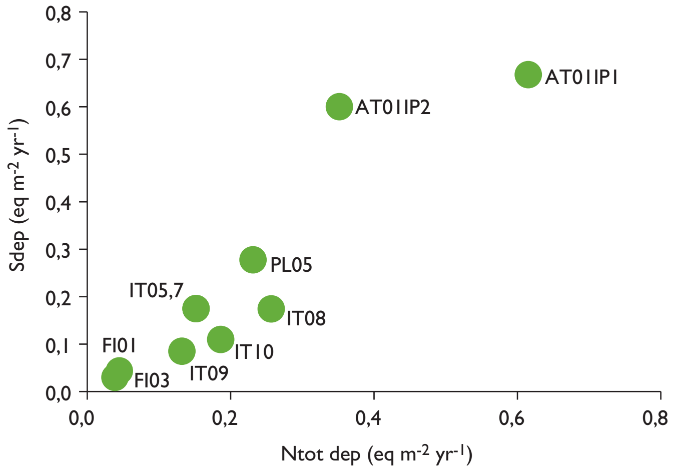


Figure 2.3. Maximum modelled deposition of S and total N (NO_3 + NH_4) at the sites.

2.5

Status and future tasks

The model chain consisting of MetHyd, GrowUp and VSD+ has been applied at ten sites in four countries (Austria, Italy, Poland and Finland). Calibration work is ongoing. In the following phase more sites will be included, and the vegetation responses will be estimated with the PROPS model and its extended database. The future impact on biodiversity will be evaluated by calculating values for the habitat suitability index HS in response to future N deposition scenarios.

Acknowledgements

We acknowledge the support of the model developers Luc Bonten, Janet Mol, Maximilian Posch, Gert Jan Reinds, Wieger Wamelink, as well as the collaboration in model application by several colleagues representing ICP IM and ICP Forest sites including

Julian Aherne, Jelena Beloica, Alessandra de Marco, Francesca Fornasier, Martin Forsius, Martyn Futter, Ulf Grandin, Juha Heikkinen, Tiina Nieminen, Antti-Jussi Lindroos, Lars Lundin, Sirpa Kleemola, Pavel Krám, Tomasz Pecka, Maija Salemaa, Milán Váňa, Jussi Vuorenmaa, Burkhard Beudert, Hubert Schulte-Bisping, Thomas Scheuschner.

References

Bonten, L., Posch, M. & Reinds, G.J. 2012. The VSD+ Soil Acidification Model. Model Description and User Manual. Version 1.01. Alterra, Wageningen, Coordination Centre for Effects, RIVM, Bilthoven. 25 p.

CCE 2014. VSD+ Suite of models. Available from http://wge-cce.org/Methods_Data/The_VSD_suite_of_models (accessed April 2014)

Coleman, K. & Jenkinson, D.S. 2005. RothC-26.3. A model for the turnover of carbon in soil. Model description and users guide. IACR Rothamsted, Harpenden, UK.

Posch, M. & Reinds, G.J. 2009. A very simple dynamic soil acidification model for scenario analyses and target load calculations. Environmental Modelling & Software 24, 329–340.

Posch, M., Hettelingh, J.-P., Slootweg, J. & Reinds, G.J. 2014. Deriving critical loads based on plant diversity targets. In: Slootweg, J., Posch, M., Hettelingh, J.-P. & Mathijssen, L. (eds.). Modelling and mapping the impacts of atmospheric deposition on plant species diversity in Europe. CCE Status Report 2014, 41–46.

Reinds, G.J., Posch, M. & Leemans, R. 2009. Modelling recovery from soil acidification in European forests under climate change. Science of the Total Environment 407, 5663–5673.

Reinds, G.J., Mol-Dijkstra, J., Bonten, L., Wamelink, W., de Vries, W., Posch, M. 2014. Chapter 4. VSD+ PROPS: Recent Developments. In: Slootweg, J., Posch, M., Hettelingh, J.-P., Mathijssen, L. (eds.) Modelling and Mapping the impacts of atmospheric deposition on plant species diversity in Europe. CCE Status Report 2014. 47–53.

Rowe, E., Emmett, B., Smart, S. 2009. A single metric for defining biodiversity damage using Habitats Directive criteria. In: Hettelingh, J.P., Posch, M., Slootweg, J. (eds.) Progress in the modelling of critical thresholds, impacts to plant species diversity and ecosystem serviceds in Europe: CCE Status Report, 101–106.

Schlütow, A., Kraft, P, Nagel, H.-D., Scheuschner, T. & Weigelt-Kirchner, R. 2010. Modelling and mapping of spatial differentiated impacts of nitrogen input to ecosystems within the framework of the UNECE – Convention of Air Pollution Prevention. The Model BERN – Assessment of Vegetation Change and Biodiversity (in German). Umweltbundesamt UBA-EB 001341. Dessau-Rosslau 123 p.

Schöpp, W., Posch, M., Mylona, S. & Johansson, M. 2003. Long-term development of acid deposition (1880-2030) in sensitive freshwater regions in Europe. Hydrology and Earth System Sciences 7, 436–446.

Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L.D., Fagerli, H., Flechard, C.R., Hayman, G.D., Gauss, M., Jonson, J.E., Jenkin, M.E., Nyíri, A., Richter, C., Semeena, V.S., Tsyro, S., Tuovinen, J.P., Valdebenito, Á. & Wind, P. 2012. The EMEP MSC-W chemical transport model- technical description. Atmos. Chem. Phys. 12, 7825–7865.

3 Progress report on trend assessment for bulk deposition, throughfall and runoff water chemistry and climatic variables at ICP IM sites in 1990–2013

Jussi Vuorenmaa, Sirpa Kleemola and Martin Forsius
Finnish Environment Institute (SYKE), P.O. Box 140, FI-00251 Helsinki, Finland

3.1
Introduction

Detrimental effects of transboundary air pollution led to international agreements to reduce emissions of sulphur and nitrogen in Europe and North America. The protocols of the United Nations Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution (UNECE CLRTAP) and legislation of the European Union have been key international instruments causing this positive development. It is essential that empirical scientific evidence based on environmental monitoring programmes is available for assessing and documenting the success and ecosystem benefits of costly international emission reduction policy. Acidification of sensitive lakes and rivers is still an environmental concern despite reduced emissions of sulphur and nitrogen (e.g. Garmo et al. 2014), and changing climate may have a large impact on water chemistry and freshwater biology (e.g. Wright & Jenkins 2001, Skjelkvåle et al. 2003, Wright et al. 2006). Moreover, several studies have also demonstrated the complexity of recovery processes and the interactions within and between the aquatic and terrestrial ecosystems and atmosphere (e.g. Rask et al. 2014). Therefore, the integrated long-term monitoring approach including physical, chemical and biological variables for detecting the variety of impacts of changing environmental conditions on ecosystems and long-term changes is clearly needed.

The multidisciplinary International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (UNECE ICP IM) under the LRTAP Convention quantifies pollutant effects on the environment through monitoring, modelling and scientific review, using data from catchments/plots located in predominantly forested natural or semi-natural areas (Forsius et al. 2001, Forsius et al. 2005, Bringmark et al. 2013, Holmberg et al. 2013). ICP IM programme has a cause-effect approach and it provides a valuable means to study the effects of air pollution and climate change in the catchments. As monitoring and evaluation of long-term changes of air pollution effects on ecosystems are one of the main objectives of the ICP IM programme, it was agreed at the ICP IM Task Force meeting in 2007 that trend analysis should be carried out regularly. The most recent extensive trend assessment for ICP IM sites was presented for the period 1993-2006 in the 18th Annual Report, including 34 sites from 13 countries (Vuorenmaa et al. 2009). In addition, trends for S and N fluxes were presented at selected 17 sites from nine countries in 1990–2012 (Vuorenmaa et al. 2014). The 23rd ICP IM Task Force discussed the collaboration with ICP Waters, with interest to harmonize IM trend assessments with ICP Waters and possibilities of aiming at common trend reporting in the future. With respect to trends in surface water chemistry, the recent ICP Waters trend reports were focused on changes

i) in 1990–2008 with a comparison of trend periods 1990–1999 and 1999–2008 (Garmo et al. 2011) and **ii)** in 2000–2011 with a prognosis for water chemical status and expected recovery in 2020 (Garmo et al. 2015). For method validation for the prognosis of future water chemistry, data from ICP IM were used.

Changes in emission reductions and emission reduction responses on deposition and surface water chemistry were more pronounced in 1990s compared to 2000s. Reductions for total sulphur and NO_x and NH_x emissions in Europe were larger in 1990s (1990–1999) than in 2000s (1999–2008), and similar pattern with a more gradual change during the 2000s was seen in S and N deposition in Europe (Aas & Vet 2011). Correspondingly, decrease of SO_4 concentrations in acid-sensitive surface waters was clearly stronger in 1990s than in 2000s, and also trends in concentrations for other indicators of chemical recovery from acidification tended to be less pronounced during the 2000s suggesting that rate of improvement of water quality has slowed (Garmo et al. 2014). Studies of input-out budgets for S and N at ICP IM sites have shown a net loss (output > input) of sulphate from internal S soil sources during the 2000s indicating that wetlands and/or forest soils are now releasing stored airborne sulphur that had accumulated in the past, whereas nitrogen is still strongly retained in undisturbed catchments (Vuorenmaa et al. 2014). Many of these S and N retention processes are sensitive to changes in climatic variables, and would therefore be affected by future climate changes. Evidently, long-term assessment of air pollution effects on ecosystems including both trends in input and output fluxes, and changes in climatic variables, gives important information for the identification of emission reduction responses, changing climate and possible interaction between different drivers in European forested catchments in the course of recent two decades. This progress report presents a work plan for a new trend assessment at ICP IM sites for the period 1990 through 2013.

3.2 Material and methods

Study sites and time spans

Trends are evaluated separately for the periods 1990−1999 and 2000−2013, and for the entire period 1990−2013 for a selection of 30 IM sites (CA01, CZ01, CZ02, DE01, DE02, EE01, EE02, FI01, FI03, GB01, GB02, IT01, IT02, IT03, IT06, IT07, IT08, IT09, IT10, IT12, LT01, LT03, LV01, LV02, NO01, NO02, SE04, SE14, SE15, SE16), with the possible addition of new Polish and Swiss sites. The selection of catchments was guided by the availability of deposition (bulk and throughfall) data and surface water chemistry and runoff volume data in the ICP IM database. For the location of the sites see Fig.1.1. in Chapter 1.

Concentrations and fluxes

Monthly concentrations and fluxes for bulk deposition (PC), throughfall deposition (TF) and runoff water (RW) or soil water (SW, if no RW data is available) are used in the trend assessment for the individual ICP IM sites. Bulk deposition, throughfall deposition and output (runoff) fluxes are calculated from the quality and quantity of water using mean monthly values for runoff water fluxes and solute concentrations.

Trends are evaluated for non-marine (x denotes non-marine fraction) sulphate (xSO_4), base cations (xCa + xMg), hydrogen ion (H^+), nitrate (NO_3), ammonium (NH_4) and ANC (Acid Neutralising Capacity). ANC is calculated as Σ (base cations) – Σ (strong acid ions) equal to Σ(Ca + Mg + Na + K) - Σ(SO_4 + NO_3 + Cl), where units are µeq $^{-1}$. Also measured alkalinity and DOC/TOC are included in the trend analyses for runoff water chemistry.

Climatic variables

Precipitation amount, runoff volume and air temperature are regularly monitored at ICP IM sites, and corresponding long-term trends for climatic variables are evaluated using monthly sum of precipitation and mean monthly runoff and air temperature.

Statistics

At each site trends in chemical concentrations and fluxes and climatic variables outlined above are analysed using the non-parametric Seasonal Kendall test (Hirsch et al. 1982) applied to monthly data. The magnitude of trend is estimated by the Theil-Sen slope estimation method (Sen 1968). The unit of the slope estimate for monthly based data is µeq l^{-1} yr^{-1} for chemical concentrations, meq m^{-2} yr^{-1} for chemical fluxes, mm yr^{-1} for monthly precipitation sum and mean monthly runoff, and °C yr^{-1} for mean monthly air temperature.

Time schedule

The trend assessment at ICP IM sites for the period 1990-2013 will be reported in the 25th Annual Report 2016, and a scientific paper will be submitted in 2017. The national focal points and the representatives for the sites will be invited to assist with these activities.

References

Aas, W. & Vet, R. 2011. Trends in chemistry of precipitation in Europe and North America in 1990–2008. In: de Wit, H. & Skjelkvåle, B.L. (eds.), Trends in precipitation chemistry, surface water chemistry and aquatic biota in acidified areas in Europe and North America from 1990 to 2008. ICP Waters Report 106/2011, Norwegian Institute for Water Research, Oslo, pp. 11–18.

Bringmark, L., Lundin, L., Augustaitis, A., Beudert, B., Dieffenbach-Fries, H., Dirnböck, T., Grabner, M-T., Hutchins, M., Kram, P., Lyulko, I., Ruoho-Airola, T. & Vana, M. 2013. Trace Metal Budgets for Forested Catchments in Europe – Pb, Cd, Hg, Cu and Zn. Water, Air, and Soil Pollution 224,1502.

Forsius, M., Kleemola, S., Vuorenmaa, J. & Syri, S. 2001. Fluxes and trends of nitrogen and sulphur compounds at Integrated Monitoring Sites in Europe. Water, Air, and Soil Pollution 130: 1641–1648.

Forsius, M., Kleemola, S. & Starr, M. 2005. Proton budgets for a monitoring network of European forested catchments: impacts of nitrogen and sulphur deposition. Ecological Indicators 5, 73–83.

Garmo, Ø.A, Skjelkvåle, B.L., Colombo, L., Curtis, C., Dubokova, I., Fölster, J., Hoffmann, A., Høgåsen, T., Jeffries, D., Keller, W.B., Majer, V., Rogora, M., Rzychon, D., Srybny, A., Steingruber, S., Stoddard, J.L., Talkop, R., Vuorenmaa, J., de Wit, H. & Worsztynowicz, A. 2011. Trends in surface water chemistry in Europe and North America 1990-2008. In: de Wit H. & Skjelkvåle B.L. (eds.), Trends in precipitation chemistry, surface water chemistry and aquatic biota in acidified areas in Europe and North America from 1990 to 2008. ICP Waters Report 106/2011, Norwegian Institute for Water Research, Oslo, pp. 19–46.

Garmo, Ø.A., Skjelkvåle, B.L., de Wit, H.A., Colombo, L., Curtis, C., Fölster, J., Hoffmann, A., Hruška, J., Høgåsen, T., Jeffries, D.S., Keller, W.B., Krám, P., Majer, V., Monteith, D.T., Paterson, A.M., Rogora, M., Rzychon, D., Steingruber, S., Stoddard, J.L., Vuorenmaa, J. & Worsztynowicz, A. 2014. Trends in Surface Water Chemistry in Acidified Areas in Europe and North America from 1990 to 2008. Water, Air, and Soil Pollution 225, 1880.

Garmo, Ø.A., de Wit, H., Høgåsen, T., Lund, E., Wright, R.F., Aherne, J., Arle, J., Colombo, L., Fölster, J., Hruška, J., Indriksone, I., Jeffries, D., Krám, P., Monteith, D.T., Paterson, A., Rogora, M., Rzychon, D., Steingruber, S., Stoddard, J.L., Talkop, R., Ulańczyk, R.P. &Vuorenmaa, J. Trends in water chemistry. In: Garmo Ø.A., De Wit, H.A. & Fjellheim A. (eds.), Chemical and biological recovery in acid-sensitive waters: trends and prognosis. ICP Waters Report 119/2015, Norwegian Institute for Water Research, Oslo. (in print)

Hirsch, R.M., Slack, J.R. & Smith, R.A. 1982. Nonparametric Tests for Trend in Water Quality. Water Resources Research 18, 107–121.

Holmberg, M., Vuorenmaa, J., Posch, M., Forsius, M., Lundin, L., Kleemola, S., Augustaitis, A., Beudert, B., Wit, H. A. de, Dirnböck, T., Evans, C. D., Frey, J., Grandin, U., Indriksone, I., Krám, P., Pompei, E., Schulte-Bisping, H., Srybny, A. & Vána, M. 2013. Relationship between critical load exceedances and empirical impact indicators at Integrated Monitoring sites across Europe. Ecological Indicators 24, 256–265.

Rask, M., Arvola, L., Forsius, M. & Vuorenmaa, J. 2014. Preface to the Special Issue ”Integrated Monitoring in the Valkea-Kotinen Catchment during 1990-2009: Abiotic and Biotic Responses to Changes in Air Pollution and Climate”. Boreal Environment Research 19 (suppl. A), 1–3.

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall’s tau. J. Am.Stat. Assoc. 63, 1379–1389.

Skjelkvåle, B.L., Evans, C., Larssen, T., Hindar, A. & Raddum, G.G. 2003. Recovery from acidification in European surface waters: A view to future. Ambio 32, 170–175.

Vuorenmaa, J., Kleemola, S. & Forsius, M. 2009. Trend assessment of bulk deposition, throughfall and runoff water/soil water chemistry at ICP IM sites. In: Kleemola, S. and Forsius, M. (eds.). 18th Annual Report 2009. UNECE ICP Integrated Monitoring. The Finnish Environment, 23/2009, 36–63. Finnish Environment Institute, Helsinki.

Vuorenmaa, J., Kleemola, S., Forsius, M., Lundin, L., Augustaitis, A., Beudert, B., de Wit, H., Frey, J., Indriksone, I., Minerbi, S., Krám, P. & Váňa, M. 2014. Sulpur and nitrogen input-output budgets at ICP Integrated Monitoring sites in Europe in 1990-1992: Progress report. In: Kleemola, S. & Forsius, M. (eds.). 23rd Annual Report, International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems. Reports of the Finnish Environment 23/2014, 28–35.

Wright, R.F. & Jenkins, A. 2001. Climate change as a confounding factor in reversibility of acidification: RAIN and CLIMEX projects. Hydrology and Earth System Sciences 5, 477–486.

Wright, R.F., Aherne, J., Bishop, K., Camarero, L., Cosby, B.J., Erlandsson, M., Evans, C.D., Forsius, M., Hardekopf, D.W., Helliwell, R., Hruška, J., Jenkins, A., Kopáček, J., Moldan, F., Posch, M. & Rogora, M. 2006. Modelling the effect of climate change on recovery of acidified freshwaters: Relative sensitivity of individual processes in the MAGIC model. Science of the Total Environment 365, 154–166.

4 Progress report on heavy metal trends at ICP IM sites

Staffan Åkerblom & Lars Lundin
Swedish University of Agricultural Sciences (SLU), Department of Aquatic Sciences and Assessment, Box 7050, SE-750 07 Uppsala, Sweden

4.1
Introduction

Long-range atmospheric transport of heavy metals has increased the exposure to forest ecosystems. Therefore trends of heavy metals have been included within the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM) to support the Convention on Long-range Transboundary Air Pollution on Heavy Metals (UNECE 2003). Such evaluations would preferably be based on a catchment concept that provides well-defined boundaries of the systems considering inputs and outputs. Such investigations are comprehensive, but the ICP IM for the UNECE region made it possible to perform Europe-wide comparisons of sites in various climates and exposure to pollution loads. Evaluations of temporal trends within ICP IM have been done in subprogrammes for precipitation chemistry (PC), throughfall (TF), litterfall (LF), runoff water (RW) and soil chemistry (SC). Catchment budgets show an ongoing accumulation of heavy metals and the release (RW) seldom exceeds input (PC + TF + LF) (Aastrup et al. 1991, Ukonmaanaho et al. 2001, Grigal 2002, Bringmark et al. 2013). The build up of heavy metals in soil stores, reflected in SC, are to a large degree dependent on long-term and long-range atmospheric transport (Lundin et al. 2001, Steinnes & Friedland 2006).

Priority heavy metals within CLRTAP and ICP IM are mercury (Hg), lead (Pb) and cadmium (Cd) (Sliggers & Kakebeeke 2004). Reported data in SC, PC, TF, LF and RW at European sites were evaluated to test for the occurrence of temporal changes/trends in metal concentrations. At Swedish ICP IM sites (Aneboda, Gårdsjön, Kindlahöjden and Gammtratten) soil samples have been collected with regular intervals over the last decades and were tested for temporal trends in more detail. We showed that heavy metal soil stores and concentrations in both input and release of Pb and Cd were decreasing at Swedish IM sites. On the other hand, concentrations of Hg in soil, surprisingly still increased. For all priority heavy metals input still exceeded output.

4.2
Material and methods

Data reported to the ICP IM Programme Centre at the Finnish Environment Institute (SYKE, Helsinki, Finland) were used for the evaluation of temporal trends. Trends in heavy metal soil concentrations (SC) were evaluated at IM sites across Europe but the annual transport on PC, TF, LF and RW were evaluated only at Swedish IM sites. Temporal trends of heavy metal concentrations were estimated by simple linear regression between sampling year and metal concentrations for each site. Reported SC at ICP IM sites outside Sweden showed sampling frequency between two and three (at a few occasions four) times between 1994 and 2011. Within soil profiles there were only one value from each soil depth reported at each time, except from Sweden where 6 samples from soil plots (50 * 50 m) were taken every 5 to 10 years.

SC heavy metal concentrations were determined in four soil layers, i.e. litter + organic layer, 0–5 cm depth, 10–20 cm depth, 30–50 cm depth and 50–cm depth and used for the trend analysis. At the four Swedish IM sites, linear regressions were used to determine temporal trends of soil metal concentrations in three layers, i.e. the FH-layer, and mineral soil at 0–5 cm and 10–20 cm depths.

For SC, Sweden excluded as separately assessed, temporal changes at each IM site and soil depth were attributed with a symbol indicating either an increase (+) or decrease (-) in metal concentration over time. Strength of the changes were indicated with either one (+/-), two (++/--) or three (+++/---) symbols. Often, the regressions were based on one sample from each of two years. Given the uncertainty for this type of data any changes between the sampling years were given one symbol for the change (+/-). With more than two years of sampling, or several samples from each soil depth, the goodness of fit (R^2) was used to determine the number of symbols for indication of temporal changes. For regression for temporal changes with $R^2 >$ 0.7, the change was given three symbols while temporal changes with $0.3 < R^2 < 0.7$ were indicated with two symbols. Temporal change with an $R^2 < 0.3$, or one sample from each of two years sampling occasions, was indicated with a single symbol (+/-). The number of increasing (+) and decreasing (-) trends from all ICP IM sites were counted and summed up for each soil depth. To test for the significance of temporal change in soil metal concentrations the proportion of sites with increasing metal concentration was tested with the exact binomial test (Conover 1971) with the null hypothesis (H_0: prop ≤ 0.5) and alternative hypothesis (H_1: prop > 0.5). This was done to indicate the occurrence of an increasing (H_1) or decreasing (H_0) change of metals for each soil depth.

4.3
Results and discussion

Trends in soil metal concentrations Europe, Sweden excluded

Significant changes were estimated from the proportion of symbols (+ and -) in the forest floor layer (litter + organic topsoil) compared to the equal proportion (indicating no change), which revealed the results Hg (2/4 = 0.5), Pb (13/21 = 0.62) or Cd (13/20 = 0.65) (Table 4.1.). In the upper mineral soil layer (0–5 cm), significant accumulations of Hg (4/4 = 1) and Pb (12/12 = 1) could be observed over time while the temporal change for Cd was weaker (6/9 = 0.67). There were more indications of increasing than decreasing trends on Cd, even though the proportion between increases and decreases at sites were not significant.

Table 4.1. The proportion of number indicating increasing (+) and decreasing (-) temporal changes in Hg, Pb and Cd soil concentrations.

Soil layer, cm	Hg		Pb		Cd	
	+	-	+	-	+	-
Litter + organic topsoil	2	2	13	8	13	7
5	4	0	12	0	6	3
10–20	2	1	9	9	12	7
30–50	0	6	15	13	8	6
50–	1	1	9	6	9	3

Sweden

For Swedish IM sites Pb concentrations in the forest floor (F+H -horizons) decreased between 1994 and 2011 in sites Aneboda, Gårdsjön and Kindla. Cadmium content decreased at Aneboda and Gårdsjön. Mercury concentrations, on the other hand, increased over the same period in Gårdsjön and Kindlahöjden. At Gammtratten no resampling was done so no time trend in the F+H -horizons could be analysed.

In mineral soil layers, at a depth between 0 and 5 cm, Pb increased in sites Gårdsjön and Gammtratten where also Cd increased as well as in Kindla. In Kindla also Hg concentration increased in the upper mineral soil horizon.

In deeper mineral soil layers (5–20 cm), Pb concentrations increased significantly at all Swedish IM sites (Fig. 4.1.). Hg concentration also showed increased values in the mineral soil at 5–20 cm depth in Kindla. No significant changes in Cd concentrations could be seen in the lower parts of the mineral soil at any site.

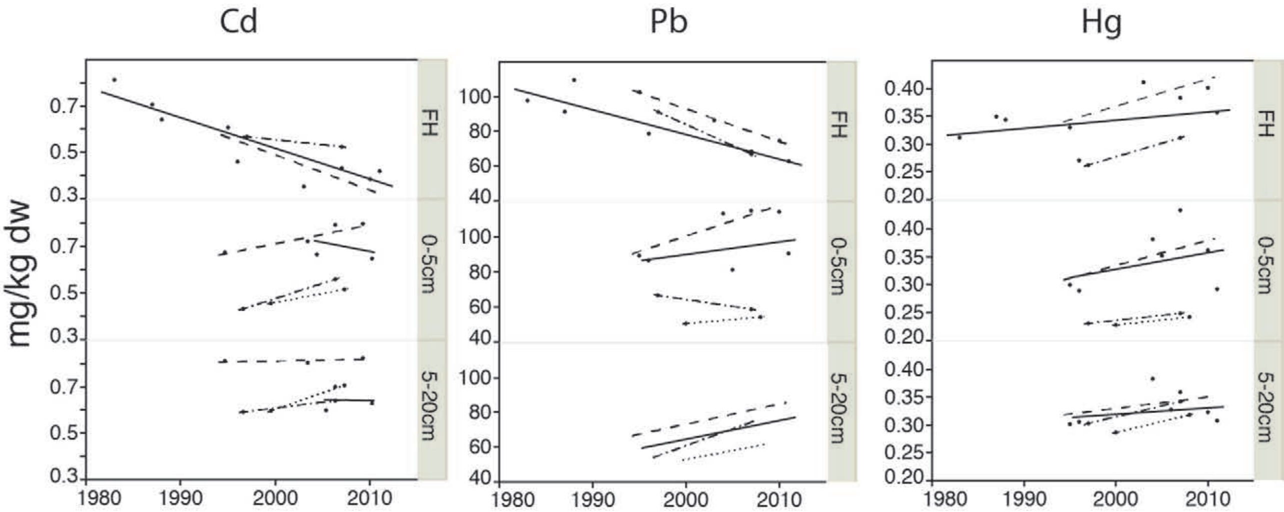


Figure 4.1. Soil metal concentrations at the four ICP IM sites in Sweden (Aneboda (solid line), Gammtratten (dotted line), Gårdsjön (dashed line), Kindla (dotdashed line)).

Trends in stream water heavy metal concentrations

Temporal trends in stream water metal concentrations were not possible to evaluate for most sites since the extracted part of the reported data covered only short sampling periods at ICP IM sites outside Sweden (2008–2010) (Fig. 4.2.). At Swedish IM sites samples were collected and analysed every month from 1994 to 2013. Cadmium concentrations decreased at sites Kindla and Gårdsjön while no significant changes were observed at the other two sites. No significant trends at the Swedish sites were detected for Pb and Hg, except for Hg at Gårdsjön where concentrations increased.

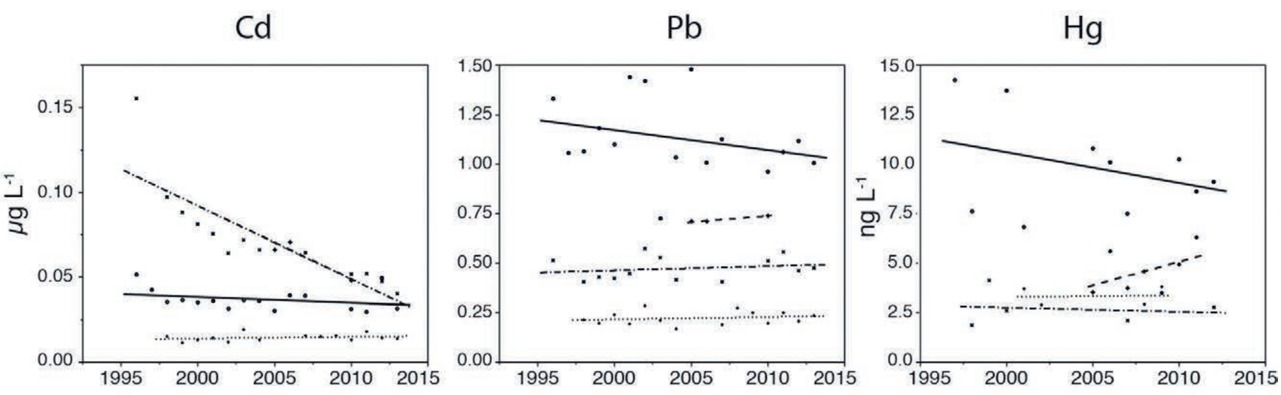


Figure 4.2. Stream water Cd and Pb (µg L^{-1}) and Hg (ng L^{-1}) concentrations at at the four ICP IM sites in Sweden (Aneboda (solid line) , Gammtratten (dotted line), Gårdsjön (dashed line), Kindla (dotdashed line)).

Trends in heavy metal transport

Annual transport of Pb showed trends that are generally decreasing at Swedish IM sites. On the other hand, trends in Cd and Hg annual transport didn't show any change or only modest decreases. Geographical variation in the observed trends was found with stronger decreasing trends at Gårdsjön (SW Sweden) while Gammtratten (NE Sweden) had smaller or no observed trends. The fact that Gammtratten showed such small changes in the annual transport might be because the levels were already low from the beginning while Gårdsjön receives heavy loads of anthropogenic heavy metal input.

All heavy metals showed exceedances in deposition compared to runoff in the range 4–52. The strongest exceedances (deposition/runoff) were found for Hg and Pb at Gårdsjön where deposition (PC+TF+LF) was 20 times higher than output (RW). At Kindla the highest exceedance was found for Hg, the annual deposition rate was more than 50 times annual runoff transport. At all sites the lowest exceedances were found in Cd ranging between 4 and 12.

4.4

Conclusions

Metals in soil and stream water are to a large degree dependent on long-term and long-range atmospheric transport, and the main CLRTAP priority has been on mercury (Hg), lead (Pb) and cadmium (Cd) (Bringmark et al. 2013). Temporal changes in metal concentrations were tested in soil and stream water at European ICP IM sites. At Swedish ICP IM sites (Aneboda, Gårdsjön, Kindla and Gammtratten) soil and stream water samples have been collected with regular intervals over the last decades and there metal concentrations were tested for temporal trends in more detail. Mainly, slightly decreasing trends were observed, more pronounced trends at site Gårdsjön.

Pb and Cd concentrations decreased in the forest floor at Swedish IM sites but accumulated in deeper mineral soil layers. At the European IM sites, different trends were observed in the forest floor, but accumulation of Cd and Pb was observed in the mineral soil layers also at IM sites outside Sweden. In spite of the decrease in Hg deposition, Hg concentrations in the forest floor increased at all Swedish IM sites.

In stream water, temporal trends of metal concentrations were not obvious, even though Cd concentrations showed decreases in Swedish streams. Large exceedances were found in deposition compared to runoff for all metals indicating an ongoing accumulation of heavy metals in the catchment despite the efforts to decrease anthropogenic emissions to the atmosphere.

References

Aastrup, M., Johnson, J., Bringmark, E., Bringmark, L. & Iverfeldt, A. 1991. Occurrence and transport of mercury within a small catchment area. Water, Air, and Soil Pollution, 56: 155–167.

Bringmark, L., Lundin, L., Augustaitis, A., Beudert, B., Dieffenbach-Fries, H., Dirnböck, T., Grabner, M-T., Hutchins, M., Kram, P., Lyulko, I., Ruoho-Airola, T. & Vana, M. 2013. Trace Metal Budgets for Forested Catchments in Europe – Pb, Cd, Hg, Cu and Zn. Water, Air, and Soil Pollution, 224: 1502, 14p.

Conover W.J. 1971. Practical Nonparametric Statistics. John Wiley & Sons, New York, pp. 97–104.

Grigal, D.F. 2002. Inputs and outputs of mercury from terrestrial watersheds: A review. Environmental Reviews 10: 1–39.

Lundin, L., Aastrup, M., Bringmark, L., Brakenhielm, S., Hultberg, H., Johansson, K. et al. 2001. Impacts from deposition on Swedish forest ecosystems identified by integrated monitoring. Water, Air, and Soil Pollution 130: 1031–1036.

Sliggers, J. & Kakebeeke, W. 2004. Clearing the Air. 25 years of the Convention on Long-range Transboundary Air Pollution. UNECE. New York and Geneva. 167 p.

Steinnes, E. & Friedland, A.J. 2006. Metal contamination of natural surface soils from long-range atmospheric transport: Existing and missing knowledge. Environmental Reviews 14: 169–186.

Ukonmaanaho, L., Starr, M., Mannio, J. & Ruoho-Airola, T. 2001. Heavy metal budgets for two headwater forested catchments in background areas of Finland. Environmental Pollution 114: 63–75.

UNECE 2003. Convention on Long-range Transboundary Air Pollution on Heavy Metals – The 1998 Aarhus protocol on heavy metals. United Nations - Economic Commision for Europe, 33 p.

5 eLTER EU/H2020 research infrastructure project: relations to ICP IM activities

Martin Forsius
Finnish Environment Institute (SYKE), P.O. Box 140, FI-00251 Helsinki, Finland
ICP IM Programme Centre

Long-Term Ecosystem Research (LTER) is an essential component of world-wide efforts to better understand ecosystems. This comprises their structure, functions, and long-term response to environmental, societal and economic drivers. LTER contributes to the knowledge base informing policy and to the development of management options in response to the Grand Challenges under global change. The European LTER-network, LTER-Europe (www.lter-europe.net) is both a network of national LTER-networks and a large research infrastructure of LTER-sites, LTSER-platforms and related databases (for details see LTER-Europe web-site). The cumulative infrastructure value of LTER-Europe has been estimated to about 450 million €.

The concepts of LTER-Europe and ICP IM are closely related, and consequently many ICP IM sites form part of the national LTER-structures. The LTER-sites cover usually larger areas, and include often other facilities such as experimental sites, field stations, other monitoring sites, managed land areas, etc. The ICP IM sites, which are located in undisturbed background areas, form part of the monitoring infrastructures of these larger LTER/LTSER-sites and platforms.

A consortium of 28 institutions involved in LTER-Europe submitted recently a research proposal to support construction of the European LTER-network. The eLTER-project received funding and will start in June 2015. Project leaders are Michael Mirtl and Herbert Haubold from the Austrian Environment Agency. The duration of the project is four years (2015-2018) and the budget about five million €. The overall aim of the eLTER-project is to advance the European network of LTER sites and socio-ecological research platforms to provide highest quality services for multiple use, enabling European-scale investigation of major ecosystems and socio-ecological systems, and targeted to support knowledge based decision making at various levels. The project has three main components (Fig. 5.1):

- Infrastructure design
- IT and data services
- Scientific testing of services

In addition to providing long-term intensive data for the general data integration and database construction of eLTER, data of the ICP IM sites will be used in the scientific applications of the project. This work will be harmonized with the general ICP IM work plan, and will provide additional financial support for the work of the scientists involved. Since ICP IM has both harmonized data available and experience of European-scale scientific evaluations (directly supporting also environmental policy development), a valuable "proof of concept" can be provided.

The main part of this scientific work will be conducted as part of the project work package "Improving and testing integrated information services for abiotic drivers and ecosystem/biodiversity response", where Martin Forsius acts as work package leader.

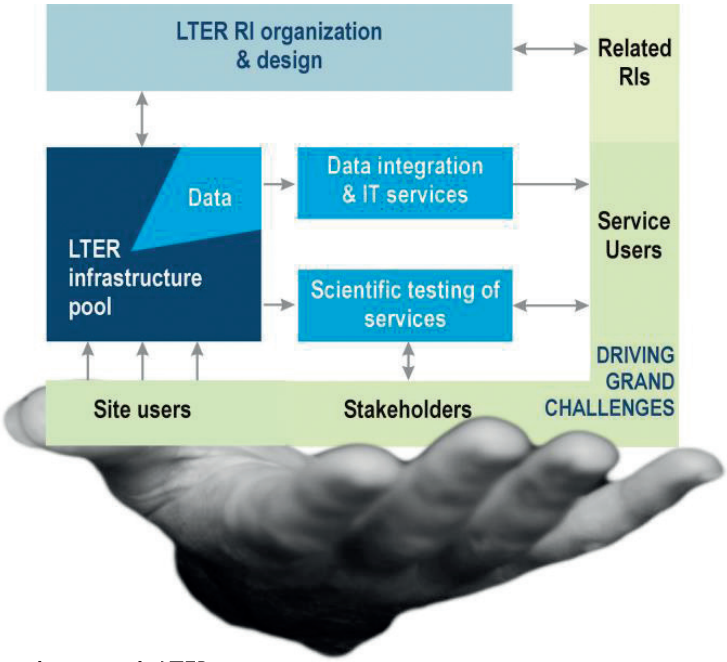


Figure 5.1. Main features of eLTER project.

The key aims of this work package are:

- Test the long-term data legacy of LTER by using field observations, protocols and data information systems within the infrastructure for method assessment, validation and development.
- Test and demonstrate large-scale, cross-site methodologies for ecosystem impact analysis.
- Set up and document an integrated ecosystem model structure for future use within LTER.
- Provide information for work under the EU No Net Loss of Biodiversity initiative.
- Test effects based methodology for nitrogen impacts analysis that is used for policy assessment in Europe (EU NEC directive, UNECE LRTAP Convention).

The work is divided into three tasks (main foreseen products indicated):

- Task 1: Integrated LTER services for climate data and climate change projections
  - climate scenarios for sites
- Task 2: Integrated services for climate change impact responses
  - meta-analysis on case studies and available data focusing on species and ecosystem responses
  - testing of indicators to detect patterns of biodiversity change
  - statistically based niche modelling to develop projections of species distributions under future climates
- Task 3: Integrated services for modelling ecosystem impacts of multiple drivers
  - set up dynamic ecosystem modelling system to forecast the impacts of N deposition and climate
  - provide calibrated model system for future use

The eLTER-project will greatly support database, indicator development and modelling work of all ICP IM sites. The project will also be an important process to enhance ecosystem research and monitoring work across the entire continent, and also improve the European component of the global LTER-network (ILTER, www.ilternet.edu).

Annex 1

Report on National ICP IM Activities in Estonia

Jane Frey[1], Naima Kabral[2], Toomas Frey[3], Reet Talkop[4]

[1] *Institute of Geography, Tartu University, Ülikooli 18, 50090 Tartu, Estonia, jane.frey@ut.ee,*
[2] *Estonian Environmental Research Centre, Marja 4D, 10617 Tallinn, Estonia, naima.kabral@klab.ee*
[3] *Institute of Silviculture, Estonian University of Life Science, toomas.frey@mail.ee*
[4] *Estonian Ministry of Environment, reet.talkop@envir.ee*

ICP IM Programme has now been carried out for 20 years (since 1995) at two monitoring areas in Estonia. Vilsandi (EE01) site is located on Estonia's westernmost island (N58º 23´, E21º 50´) and Saarejärve (EE02) is located in a forested sub-catchment area (109 ha) of Lake Saare in eastern Estonia (N58º 39´, E26º 45´). In 2014 the sampling and measurements were run under the ICP IM sub-programmes: AM, AC, PC, TF, SF, SW, FC, LF, FD, EP, MB at both of the areas and, additionally, under RW, TA and AL at the Saarejärve IM area.

Hydrological fluxes in 2014

Annual water fluxes are presented in Table 1. At Vilsandi site annual bulk precipitation in 2014 was the lowest (582 mm) in the past eight years. At the inland Saarejärve site annual bulk precipitation flux (669 mm) was pretty much the same as the averages for the monitoring period (Table 1). August was characteristically the highest precipitation month of the year (188 mm at Vilsandi, 165 mm at Saarejärve), however, September, October and November were drier than usual at both monitoring areas. Precipitation distribution between months was rather homogeneous – runoff water flux from Saarejärve catchment area was registered in 289 days of the year and the annal runoff water flux (148 mm) was higher than the average and accounts for 22 % of the annual precipitation (Table 1).

Table 1. Stand characteristics and water fluxes (mm) in 2014 compared with average annual water fluxes in 1995-2011 (in brackets) at the permanent plots of Estonian integrated monitoring areas.

Permanent plot	Vilsandi (EE01) pine stand	Saarejärve (EE02) pine stand	Saarejärve (EE02) spruce stand
Site type	*Fragario-Pinetum*	*Rhodococco-vitis-idaeo-Pinetum*	*Vaccino-myrtilli-Piceetum*
Soil type	*Calcsri-Gleyic Leptosol*	*Haplic Podzol*	*Haplic Podzol*
Bulk precipitation (mm)	582 (538)	669 (667)	
Throughfall (mm)	393 (304)	494 (542)	494 (464)
Soil water from depth of 10 cm (mm)	151 (113)	44 (59)	93 (116)
Soil water from depth of 40 cm (mm)	75 (98)	32 (29)	54 (80)
Runoff water (mm)	-	148 (117)	

Deposition loads in 2014

The inland Saarejärve IM site was characterised by higher pH in deposition compared to the insular Vilsandi site throughout the monitoring period, but the highest annual average pH=6.6 of bulk precipitation and pH=6.0 of pine stand throughfall were obtained in 2014. In Vilsandi the annual average pH of bulk precipitation and pine stand throughfall varied between 4.8 and 4.7, both in 2014 and during the whole period (Fig. 1).

Reduction of SO_4-S has lasted throughout the monitoring period in bulk precipitation and throughfall of the pine and spruce stands at Saarejärve station. In 2014 the annual open area deposition of sulphur was 2.3 kg S ha^{-1}, the throughfall loads were 3.3 and 2.3 kg S ha^{-1} in the pine stand and spruce stand, respectively. Lower S deposition load in the spruce stand is a result of bark beetle attacks caused by the drying process of canopy. In 2014 the annual S load by bulk precipitation at Vilsandi was 2.0 kg S ha^{-1}, which is the lowest load registered during the 20-year monitoring period. The annual bulk deposition of sulphur has declined from 4.9 kg S ha^{-1} (90% of which was of marine and 10% of anthropogenic origin) in 1995 to 2.0 kg S ha^{-1} in 2014 (80% and 20%, respectively). The decreasing time trend is statistically significant. However, a downward trend of SO_4-S is not evident in throughfall of the pine stand. The higher throughfall precipitaton fluxes since 2009 are one reason for the higher deposition loads of S in the pine stand in the past five years. The annual throughfall load of 3.8 kg S ha^{-1}, estimated in 2014, was also the lowest throughfall deposition during the monitoring period (Fig. 1). Remarkably high throughfall loads of SO_4-S and Cl during 2009–2013 could be some marine weather effect on pine canopy, or indicate an increase in the occurrence of stormy sea.

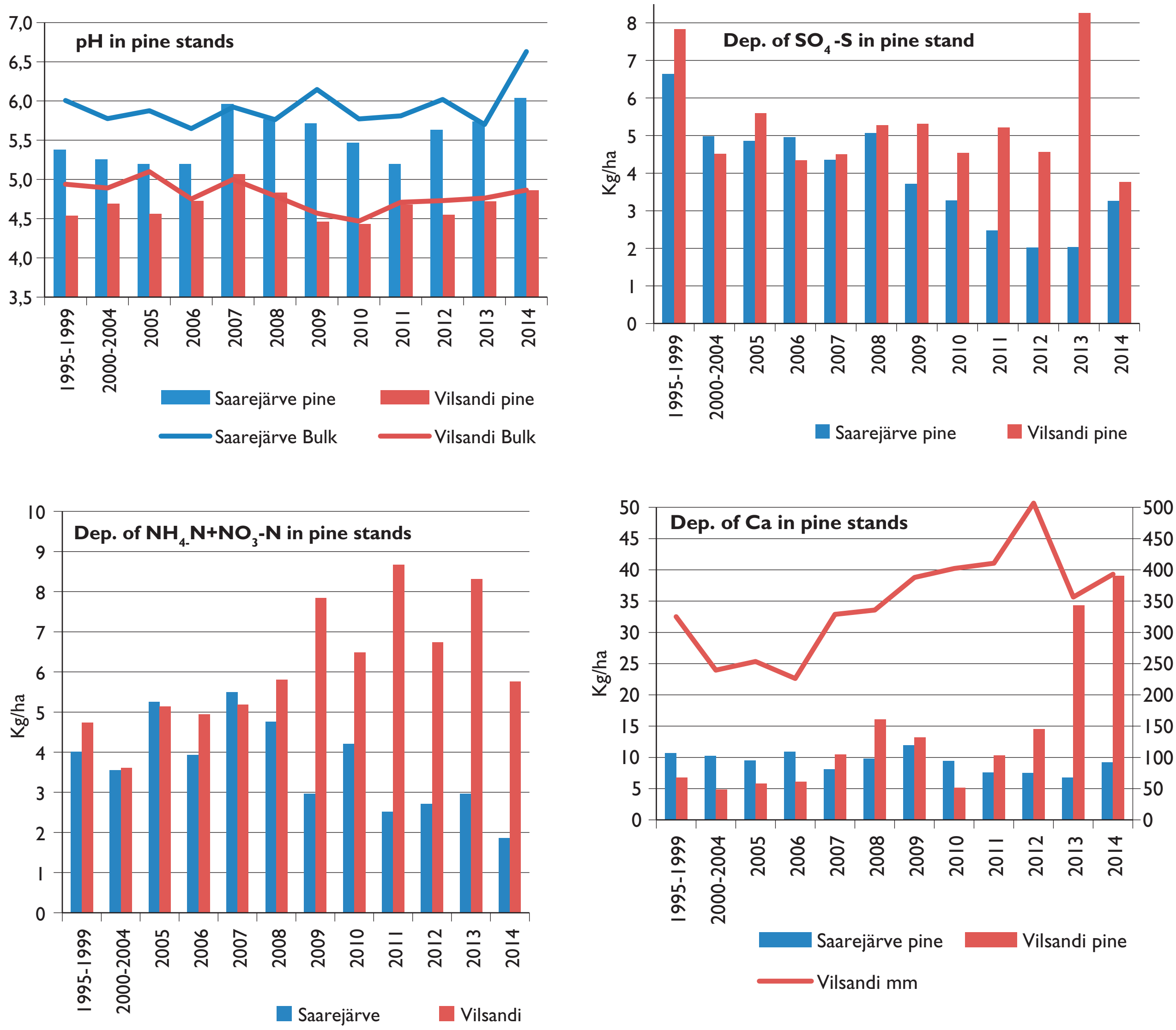
Inorganic N deposition (NO_3-N+NH_4-N) was the lowest at Saarejärve throughout the monitoring period: 2 kg N ha^{-1} by bulk precipitation and in pine throughfall, and 0.6 by spruce throughfall. Inorganic N loads by throughfalls in the pine and spruce stands have remained below 3 kg in the last three years. In contrast, in Vilsandi pine stand inorganic nitrogen loads were nearly always higher than at Saarejärve, but during the past five years (since 2009), these values increased and varied between 6.5 up to 8.7 kg ha^{-1}. In 2014 the NH_4-N+NO_3-N load in Vilsandi pine stand was 5.8 kg ha^{-1} (Fig. 1). The increase in N load has led to depletion of the moss carpet and dominance of herbaceous plants in the bottom layer of the pine stand (by VG in 2011). These changes are probably caused by flocks of sheeps and herds of highland cattle in summer, and increased traffic due to rising recreational load on the island.

An increased tourism load, repair of local gravel roads and active building work can be regarded as the reason for very high Ca deposition (Fig. 1) in last two years (34 and 39 kg ha^{-1} in the pine stand) in Vilsandi (Table 2).

Table 2. Deposition loads in 2014 compared with average annual loads during 2000-2010 (in brackets) at permanent plots of Estonian integrated monitoring areas.

Bulk deposition kg ha^{-1} yr^{-1}	EE01(Vilsandi)	EE02 (Saarejärve)	
pH	4.9 (4.8)	6.6 (5.8)	
SO_4-S	2.0 (2.9)	2.3 (3.0)	
NO_3-N+NH_4-N	3.5 (4.4)	1.9 (4.3)	
N_{Tot}	4.9 (7.3)	3.2 (6.3)	
Cl	6.6 (8.2)	2.3 (4.2)	
Ca	6.3 (2.8)	4.9 (6.5)	
Throughfall deposition kg ha^{-1} yr^{-1}	Pine stand	Pine stand	Spruce stand
pH	4.9 (4.7)	6.0 (5.3)	5.9 (5.3)
SO_4-S	3.8 (4.7)	3.3 (4.6)	2.3 (5.1)
NO_3-N+NH_4-N	5.8 (4.8)	1.9 (4.0)	0.6 (2.9)
N_{Tot}	8.9 (7.6)	5.0 (6.8)	3.9 (5.5)
Cl	32.5 (31.4)	6.5 (7.7)	5.4 (7.0)
Ca	39.0 (7.3)	9.2 (9.9)	5.9 (9.3)

Figure 1. Comparison of the deposition of main ions (kg per hectare in year) and pH in pine stand throughfall at Vilsandi (EE01) and Saarejärve (EE02) monitoring areas during 1995-2014.



Heavy metals data

Detailed heavy metal investigations have been carried out under the ICP IM sub-programmes: FC, LF, SC, MC and TA (in fine roots) at both areas, and under PC, TF and SW at Vilsandi IM area. The heavy metal data are used in publications:

- BIOGEOMON 2014. The 8th International Symposium on Ecosystem Behavior. Poster: Napa, Ü., Kabral, N., Ostonen, I. & Frey, J. Input of heavy metals, accumulation in soil organics and retention in fine roots of coniferous stands at ICP IM areas in Estonia.
- Napa, Ü., Kabral, N., Liiv, S., Asi, E., Timmusk, T. & Frey, J. 2015. Current and historical patterns of heavy metals pollution in Estonia as reflected in natural media of different ages: ICP Vegetation, ICP Forests and ICP Integrated Monitoring data. Ecological Indicators, Vol. 52, pp. 31–39.

Annex 2

The Integrated Environmental Monitoring Programme in Poland 2015–2017

The purpose of the Integrated Environmental Monitoring Programme (IEMP) under implementation in Poland since 1994 is:

- to gather and provide information on the current status and developmental trends of some selected geo-ecosystems in Poland,
- to specify the types of threats to the environment, interactions between its abiotic and biotic components and
- to present the prospects of the natural environment and its transformations at a local, regional and national level for various time intervals.

The initiative will be implemented under the research and measuring project under the Integrated Environmental Monitoring Programme at eleven Base Stations located in selected representative geo-ecosystems (representative basins) in Poland.

In contrast to the specialized monitoring, the IEMP comprehensively covers the natural environment on the basis of focused stationary research, and its aim is to run observations on the largest possible number of abiotic and biotic components of the natural environment. The IEMP is projected to register and analyse short- and long-term changes taking place in the geo-ecosystems under the influence of climatic changes and human interference. The obtained results will enable to make forecasts which will provide additional information for use in the form of protective measures.

Currently, the Integrated Environmental Monitoring Programme is implemented in eleven Base Stations (Fig. 1) which reflect selected Polish landscapes and are considered to be representative for the landscape structure of Poland. In addition, there is one Polar Station in Spitsbergen, which is the reference station of environmental changes in Poland.

The IEMP stations are located in typical Polish landscapes:

- sea coast (the Wolin Base Station – Adam Mickiewicz University in Poznań),
- young-glacial landscapes of the Pomeranian Lake District (the Storkowo Base Station – Adam Mickiewicz University in Poznań),
- the Mazurian Lake District (the Puszcza Borecka Base Station – the Institute of Environmental Protection) and
- the Suwalskie Lake District (the Wigry Base Station – the Wigry National Park),
- lowland landscapes (the Koniczynka Base Station – Mikołaj Kopernik University in Toruń, the Kampinos Base Station – the Kampinos National Park and the Różany Strumień Base Station – Adam Mickiewicz University in Poznań),
- highland and low mountainous landscapes (the Święty Krzyż Base Station – Jan Kochanowski University in Kielce and the Roztocze Base Station – the Roztocze National Park) and
- medium mountainous landscapes (the Szymbark Base Station – the Institute of Geography and Spatial Organisation, Polish Academy of Sciences and the Karkonosze Base Station – the Karkonosze National Park).

Figure 1. The location of Integrated Environmental Monitoring Programme Base Stations in landscape-ecological zones (Kostrzewski et al. 2014).

Table 1. Physicogeographical characteristics of representative catchment areas of the Integrated Environmental Monitoring Programme (Kostrzewski et al. 2014).

IEMP Station	Catchment research	Area [km²]	Landscape -ecological zone	Catchment/ Basin	Physical-geographic macro-region
Wolin	Gardno Lake	2.6	Baltic Sea	Baltic Sea	Szczecin Coastland
Storkowo	Parsęta	74.0	Lakelands	Parsęta	Westpomeranian Lakeland
Puszcza Borecka	Łękuk Lake	13.3	Lakelands	Węgorapa/ Pregoła	Masurian Lakeland
Wigry	Czarna Hańcza	7.4	Lakelands	Niemen	Lithuanian Lakeland
Koniczynka	Struga Toruńska	35.2	Lakelands	Wisła	Chelmno-Dobrzyn Lakeland
Różany Strumień	Różany Stream	10.1	Lakelands	Warta/Odra	Poznań Lakeland
Kampinos	Olszowiecki Channel	20.2	Lowlands	Łasica/Wisła	Central Mazovia Lowland
Święty Krzyż	I rank catchment	1.3	Uplands	Kamienna/Wisła	Kielce-Sandomierz Upland
Roztocze	Świerszcz	46.5	Uplands	Wieprz/Wisła	Roztocze
Szymbark	Bystrzanka	13.0	Medium-high Mountains	Ropa/Wisła	Central Beskydy Mountains/Central Beskydy Foothills
Karkonosze	Wrzosówka	93.2	Medium-high Mountains	Kamienna/Odra	Giant Mountains

The scope of the IEMP in the 2015-2017

Measurement Programs:

1. meteorology,
2. air pollution,
3. precipitation chemistry,
4. throughfall chemistry,
5. stemflow chemistry,
6. soil sollutions chemistry,
7. groundwater,
8. surface water - rivers,
9. surface water - lakes,
10. organic delivery,
11. heavy metals and sulphur in lichens
12. arboreal epiphytes,
13. structure and dynamics of plant cover,
14. plants invasive species of foreign origin,
15. trees and forests damage,
16. rivers hydrobiology - macrophytes and hydromorphological status,
17. evaluation of geoecosystems services.

Analytical Programs:

1. extreme events,
2. changes in land cover and land use,
3. modeling of water and biogeochemical balance changes for representative catchment,
4. functioning of research geoecosystems using geo and biomarkers

Basic Measurement Program

MEASUREMENT PROGRAM A1: METEOROLOGY

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
atmospheric pressure	PRES	hPA	1/day
air temperature at 2 m	TA_D	°C	1/day
minimum air temperature at 2 m	TA_N	°C	1/day
maximum temperature at 2 m	TA_X	°C	1/day
minimum air temperatures above the ground (at 5 cm)	TA_G	°C	1/day
ground temperature at depths: 5, 20, 50 cm	T_S	°C	1/day
relative humidity at 2 m	HH	%	1/day
amount of rainfall at 1m	RR_T	mm	1/day
amount of atmospheric deposits	RR_S	mm	1/day
wind speed at 10 m	WIV	m/s	1/day
wind direction at 10 m	WID	[-]	1/day
amount of snow cover	SC_H	cm	1/day
sunshine duration	SOL_P	min	1/day
total radiation intensity	SOL_T	W/m^2	1/day

MEASUREMENT PROGRAM B1: AIR POLLUTION

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
sulphur in sulphur dioxide $S\text{-}SO_2$ (determined by the passive method)	SO2S	ug/m^3	1/month
nitrogen in the nitrogen dioxide $N\text{-}NO_2$ (determined by the passive method)	NDON	ug/m^3	1/month
sulphur dioxide SO_2 (determined by the automatic method)	SO2S	ug/m^3	1/day
nitrogen dioxide NO_2 (determined by the automatic method)	NDON	ug/m^3	1/day

MEASUREMENT PROGRAM C1: PRECIPITATION CHEMISTRY

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
electrolytic conductivity	COND	mS/m	1/month
reaction(pH)	PH	[-]	1/month
sulphate sulphur $S\text{-}SO_4$	SO4S	mg/dm^3	1/month
nitrate nitrogen $N\text{-}NO_3$	NO3N	mg/dm^3	1/month
ammonia nitrogen $N\text{-}NH_4$	NH4N	mg/dm^3	1/month
chlorides Cl	CL	mg/dm^3	1/month
sodium Na	NA	mg/dm^3	1/month
potassium K	K	mg/dm^3	1/month
calcium Ca	CA	mg/dm^3	1/month
magnesium Mg	MG	mg/dm^3	1/month

MEASUREMENT PROGRAM C2: THROUGHFALL CHEMISTRY
MEASUREMENT PROGRAM C2: STEMFLOW CHEMISTRY
MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
throughfall stemflow	RR_TF RR_SF	mm	1/month
electrolytic conductivity	COND	mS/m	1/month
reaction(pH)	PH	[-]	1/month
sulphate sulphur S-SO_4	SO4S	mg/dm^3	1/month
nitrate nitrogen N-NO_3	NO3N	mg/dm^3	1/month
ammonia nitrogen N-NH_4	NH4N	mg/dm^3	1/month
chlorides Cl	CL	mg/dm^3	1/month
sodium Na	NA	mg/dm^3	1/month
potassium K	K	mg/dm^3	1/month
calcium Ca	CA	mg/dm^3	1/month
magnesium Mg	MG	mg/dm^3	1/month

MEASUREMENT PROGRAM F1: SOIL SOLUTIONS CHEMISTRY
MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
electrolytic conductivity	COND	mS/m	1/month
reaction(pH)	PH	[-]	1/month
bicarbonates (pH>4.5)	HCO3	mg/dm^3	1/month
sulphate sulphur S-SO_4	SO4S	mg/dm^3	1/month
nitrate nitrogen N-NO_3	NO3N	mg/dm^3	1/month
ammonia nitrogen N-NH_4	NH4N	mg/dm^3	1/month
total phosphorus PTOT	PTOT	µg/dm^3	1/month
chlorides Cl	CL	mg/dm^3	1/month
sodium Na	NA	mg/dm^3	1/month
potassium K	K	mg/dm^3	1/month
calcium Ca	CA	mg/dm^3	1/month
magnesium Mg	MG	mg/dm^3	1/month
total aluminum Al_{TOT}	ALTOT	µg/dm^3	1/month

MEASUREMENT PROGRAM F2: GROUNDWATER

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
groundwater level or the source efficiency	WL SPRING_D	cm u.g.l.	1/month
water temperature	TEMP	°C	1/month
reaction pH	PH	pH	1/month
electrolytic conductivity	COND	mS/m	1/month
bicarbonates (pH>4.5)	HCO3	mg/dm^3	1/month
sulphate sulphur $S\text{-}SO_4$	SO4S	mg/dm^3	1/month
nitrate nitrogen $N\text{-}NO_3$	NO3N	mg/dm^3	1/month
ammonia nitrogen $N\text{-}NH_4$	NH4N	mg/dm^3	1/month
total phosphorus P_{TOT}	PTOT	$\mu g/dm^3$	1/month
chlorides Cl	CL	mg/dm^3	1/month
sodium Na	NA	mg/dm^3	1/month
potassium K	K	mg/dm^3	1/month
calcium Ca	CA	mg/dm^3	1/month
magnesium Mg	MG	mg/dm^3	1/month
BZT5	BZT5	mgO_2/dm^3	1/month
dissolved oxygen	O2	mg/dm^3	1/month

MEASUREMENT PROGRAM H1: SURFACE WATER - RIVERS

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
flow based on the current flow curve	Q_E	m^3/s	1/day
water temperature	TEMP	°C	1/month
reaction pH	PH	pH	1/month
electrolytic conductivity	COND	mS/m	1/month
bicarbonates (pH>4.5)	HCO3	mg/dm^3	1/month
sulphate sulphur $S\text{-}SO_4$	SO4S	mg/dm^3	1/month
nitrate nitrogen $N\text{-}NO_3$	NO3N	mg/dm^3	1/month
ammonia nitrogen $N\text{-}NH_4$	NH4N	mg/dm^3	1/month
total phosphorus P_{TOT}	PTOT	$\mu g/dm^3$	1/month
chlorides Cl	CL	mg/dm^3	1/month
sodium Na	NA	mg/dm^3	1/month
potassium K	K	mg/dm^3	1/month
calcium Ca	CA	mg/dm^3	1/month
magnesium Mg	MG	mg/dm^3	1/month
BZT5	BZT5	mgO_2/dm^3	1/month
dissolved oxygen	O2	mg/dm^3	1/month
trophic state			1/month

MEASUREMENT PROGRAM H2: SURFACE WATER - LAKES

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
water level	WL	cm	I/day
water temperature	TEMP	°C	every 3 months
reaction pH	PH	pH	every 3 months
electrolytic conductivity	COND	mS/m	every 3 months
bicarbonates (pH>4.5)	HCO3	mg/dm^3	every 3 months
sulphate sulphur $S\text{-}SO_4$	SO4S	mg/dm^3	every 3 months
nitrate nitrogen $N\text{-}NO_3$	NO3N	mg/dm^3	every 3 months
ammonia nitrogen $N\text{-}NH_4$	NH4N	mg/dm^3	every 3 months
total phosphorus $P_{TOT.}$	PTOT	$\mu g/dm^3$	every 3 months
chlorides Cl	CL	mg/dm^3	every 3 months
sodium Na	NA	mg/dm^3	every 3 months
potassium K	K	mg/dm^3	every 3 months
calcium Ca	CA	mg/dm^3	every 3 months
magnesium Mg	MG	mg/dm^3	every 3 months
BZT5	BZT5	mgO_2/dm^3	every 3 months
dissolved oxygen	O2	mg/dm^3	every 3 months
trophic state			every 3 months

MEASUREMENT PROGRAM G2: ORGANIC DELIVERY

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
organic delivery (dry weight)	LDEP_D	g/m^2	I/month
total organic carbon C_{org}	TOC	mg/kg	I/year from monthly samples
total sulphur S	STOT	mg/kg	I/year from monthly samples
total nitrogen N.	NTOT	mg/kg	I/year from monthly samples
total phosphorus P_{TOT}	PTOT	mg/kg	I/year from monthly samples
calcium Ca	CA	mg/kg	I/year from monthly samples
magnesium Mg	MG	mg/kg	I/year from monthly samples
sodium Na	NA	mg/kg	I/year from monthly samples
potassium K	K	mg/kg	I/year from monthly samples

MEASUREMENT PROGRAM D1: HEAVY METALS AND SULPHUR IN LICHENS

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
cadmium Cd	CD	ug/g	every 2 years
lead Pb	PB	ug/g	every 2 years
zinc Zn	ZN	ug/g	every 2 years
copper Cu	CU	ug/g	every 2 years
iron Fe	FE	ug/g	every 2 years
chromium Cr	CR	ug/g	every 2 years
nickel Ni	NI	ug/g	every 2 years
sulphur S	S	ug/g	every 2 years

MEASUREMENT PROGRAM M1: ARBOREAL EPIPHYTES

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
coverage	COVE	cm^2	1/year
health	HEALTH_L	[1-5]	1/year
size of the study area	AREA_R	cm^2	1/year

MEASUREMENT PROGRAM K1: TREES AND FORESTS DAMAGE

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
defoliation	DEFO	%	1/year
discoloration	DISC	%	1/year
diameter at trunk breast height (diameter at 1.3 m height)	DBH	cm	every 5 years

MEASUREMENT PROGRAM E1: SOILS

MEASUREMENT PARAMETERS

Parameter	parameter code	denomination	frequency measurement
suspension reaction (pH) in H_2O	PH_EW20	pH in 20°C	every 10 years
suspension reaction (pH) in $CaCl_2$	PH_EC20	pH in 20°C	every 10 years
suspension reaction (pH) in w KCl	PH_EK20	pH in 20°C	every 10 years
exchangeable acidity	ACI_ET	me/kg	every 10 years
total exchangeable acidity	ACI_ETB	me/kg	every 10 years
effective cation exchange capacity	CEC_E	me/kg	every 10 years
potential cation exchange capacity	CEC_P	me/kg	every 10 years
sorption complex saturation of alcali	BASA	%	every 10 years
removable aluminum Al^{+3}	AL_E	me/kg	every 10 years
removable calcium Ca^{+2}	CA_E	me/kg	every 10 years
removable magnesium Mg^{+2}	MG_E	me/kg	every 10 years
removable potassium K^+	K_E	me/kg	every 10 years
removable sodium Na^+	NA_E	me/kg	every 10 years
removable nitrogen $N_{ogól}$	NTOT	mg/kg	every 10 years
total organic carbon C_{org}	TOC	mg/kg	every 10 years
volumetric density	BDEN	kg/m^3	every 10 years
amorphous iron oxides	FEOX_A	mg/kg	every 10 years

MEASUREMENT PROGRAM J3: MONITORING OF INVASIVE PLANT SPECIES

The new program will cover research on the threat to biodiversity arising from the invasion of non-native plant species only (currently this has been the second most relevant factor limiting the global biodiversity).

The measurement program will be implemented throughout the catchment area and at some selected solid surfaces.

MEASUREMENT PROGRAM: HYDROBIOLOGY OF RIVERS - MACROPHYTES AND HYDROMORPHOLOGICAL EVALUATION OF THEIR RIVERBEDS

The hydrobiology of rivers based on macrophytes enables to assess the quality of waters on the grounds of the determined ecological status of water eco-systems. It is the method required by the Water Framework Directive.

Assessment systems based on water plants exhibit trophic changes in the environment and are applied in Europe. The research consists in the specification of macrophytes being present within some selected 100-metre river sections. The adopted method is based on quantitative and qualitative assessment of species composition. The system makes use of 151 indicative macrophyte species.

The macrophyte research is supplemented with hydromorphological assessments of habitats made in line with the British principles of the River Habitat Survey (RHS) method. The system is used to assess the nature of habitat and quality of water courses, their selected morphological and hydrological parameters. The measuring method is based on visual valorisation conducted in the field at 500-metre river sections.

MEASUREMENT PROGRAM: SERVICES PROVIDED BY GEO-ECOSYSTEMS

The aim of the research program is to recognize and assess environmental services provided by some selected geo-ecosystems in Poland. The implementation of the research program will serve to fulfil the Strategy on Biological Biodiversity within the European Union which under the Objective 2, Action 5 calls upon Member States to identify and assess the state of ecosystems and their services within their territories up to 2014. The research program will cover some selected geo-ecosystem services (services provided by geo-ecosystems) the recognition, assessment and reporting of which are recommended by the European Union in the instructions prepared under the auspices of their agencies the European Environment Agency (EEA), and the Joint Research Centre (JRC).

The diagnosed services of geo-ecosystems will be included in the nomenclature and classification of the standardized classification of eco-system services suggested by the EEA (Common International Classification of Ecosystem Services – CICES). All the research on services provided by geo-ecosystems in Poland will also take into consideration the instructions recommended by the MAES – EU Working Group on Mapping and Assessment of Ecosystems and their Services. The adopted approach will ensure consistency of the obtained results with the recognized categorizations and concepts; it will allow for easy transfer of data on geo-ecosystem services to the reporting systems at the national and the European Union level.

References

Kostrzewski, A., Mizgajski, A., Stępniewska, M., Tylkowski, J. 2014. The use of integrated environmental programme for ecosystem services assessment. Ekonomia i Środowisko, 4(51): 94-101.

Annex 3

Report on National ICP IM activities in Sweden 2013−2015

Lundin, L.[1], Löfgren, S.[1], Kajsa Bovin[2], Grandin, U.[1], Pihl Karlsson, G.[3], Moldan, F.[3] and Thunholm, B[2].

[1] Swedish University of Agricultural Sciences (SLU), Department of Aquatic Sciences and Assessment, Box 7050, SE-750 07 Uppsala, Sweden, e-mail: lars.lundin@slu.se

[2] Geological Survey of Sweden (SGU), Box 670, SE-751 28 Uppsala, Sweden.

[3] Swedish Environmental Research Institute, Box 47086, SE-402 58 Gothenburg, Sweden.

The programme is funded by the Swedish Environmental Protection Agency.

Introduction

The Swedish integrated monitoring programme is run on four sites distributed from south central Sweden (SE14 Aneboda) over the middle part (SE15 Kindla), to a northerly site (SE16 Gammtratten). The long-term monitoring site SE04 Gårdsjön F1 is complementary on the inland of the West Coast and has been influenced by long-term high deposition loads. The sites are well-defined catchments with mainly coniferous forest stands dominated by bilberry spruce forests on glacial till deposited above the highest coastline. Hence, there has been no water sorting of the soil material. Both climate and deposition gradients coincide with the distribution of the sites from south to north (Table 1). The forest stands are mainly over 100 years old and at least three of them have several hundred years of natural continuity. Until the 1950's, the woodlands were lightly grazed in restricted areas. In early 2005, a heavy storm struck the IM site Aneboda, SE14. Compared with other forests in the region, however, this site managed rather well and roughly 20–30% of the trees in the area were storm-felled. In 1996, the total number of large woody debris in the form of logs was 317 in the surveyed plots, which decreased to 257 in 2001. In 2006, after the storm, the number of logs increased to 433, corresponding to 2711 logs in the whole catchment. In later years, 2007–2010, bark beetle (*Ips typographus)* infestation has almost totally erased the old spruce trees. In 2011 more than 80% of the trees with a breast height over 35 cm where dead (Löfgren et al. 2014) and currently almost all spruce trees with diameter of ≥20 cm are gone.

Table 1. Geographic location and long-term climate at the Swedish IM sites.

	SE04	SE14	SE15	SE16
Latitude; Longitude	N 58° 03′; E 12° 01′	N 57° 05′; E 14° 32′	N 59° 45′; E 14° 54′	N 63° 51′; E 18° 06′
Altitude, m	114–140	210–240	312–415	410–545
Area, ha	3.7	18.9	20.4	45
Mean annual temperature, °C	+6.7	+5.8	+4.2	+1.2
Mean annual precipitation, mm	1000	750	900	750
Mean annual evapotransporation, mm	480	470	450	370
Mean annual runoff, mm	520	280	450	380

In the following, climate, hydrology, water chemistry and some ongoing work at the four Swedish IM sites are presented (Löfgren 2015).

Climate and Hydrology in 2013

In 2013, the annual mean temperatures were similar to the long-term mean (1961–1990) for the two southern sites, while the two northern sites had approximately one degree higher annual means. Compared with the measured time series, 14 years at site SE16 and 18 years at the other sites, the temperatures in 2013 were on average for the two northern sites but somewhat higher at the southern sites. This resembles the year 2010 when temperatures mainly were lower than normal. Low temperatures were observed in 2010 and 2012 while 2011 temperatures were higher. Variations between years have been considerable, especially for the last five years, up to three degrees. Smaller variations were seen at the central site SE15 Kindla with only one degree.

Precipitation in 2013 showed lower values compared to the long-term average (1961—1990). For site SE04 Gårdsjön the amount was 51 mm (5%) lower, at SE14 Aneboda the deviation to normal was 193 mm (26%), for SE15 Kindla 225 mm (25%) and the northern site SE16 Gammtratten 129 mm (18%) lower than the long-term mean. In 2012, precipitation was higher than the long-term average with 3–44% for the four sites. Also 2011, the two southern sites had higher precipitation (SE14: 7% and SE04: 25%), while the sites further north only reached approximately 70% of the long-term averages.

The characteristic annual hydrological patterns of the catchments are for the southern sites high groundwater levels during winter and lower levels in summer and early autumn. Evapotranspiration has decisive influence on the runoff pattern. In 2013, these patterns were fairly typical, especially for the two northern sites. The two southern sites showed also comparably normal discharge patterns but with a tendency to a small spring flow peak, related to a cold early spring followed by rather high rainfall furnishing high discharge (Fig. 1).

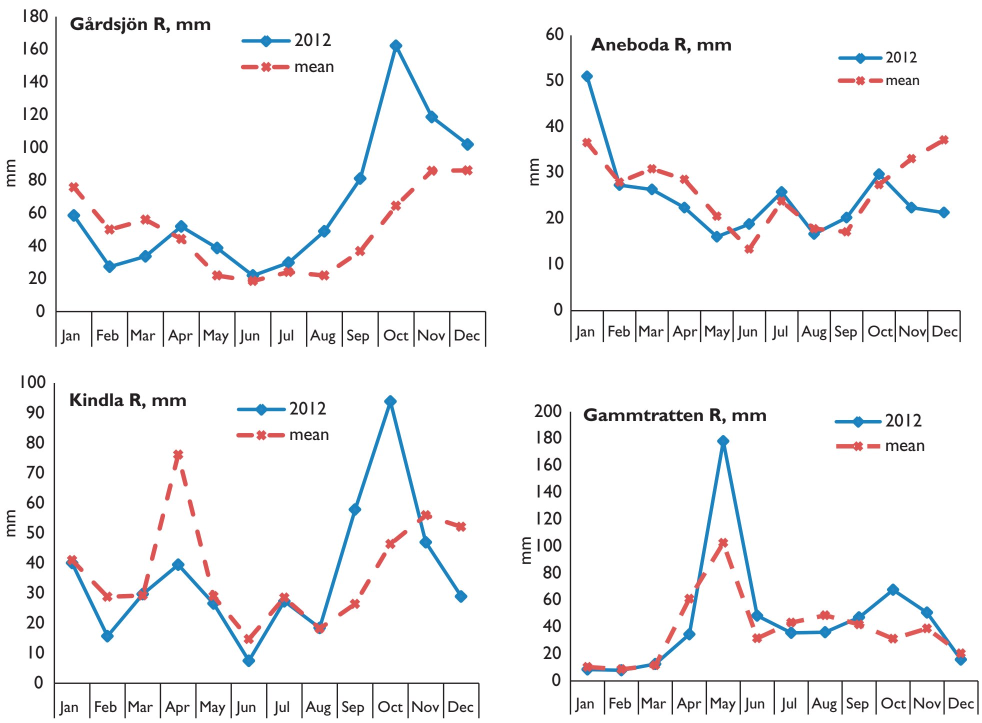


Figure 1. Discharge patterns at the Swedish IM sites in 2013 compared to monthly averages for the period 1996 – 2013 (mean). Note the different Y-axis scales.

At the two northern sites, generally snow accumulates during winter and groundwater levels stay low furnishing low discharge. However, warm periods in the winter period with temperatures above 0 °C have during a number of years contributed to snowmelt and runoff also in the winter period. As a consequence, spring discharges have been comparably low in the snowmelt period deviating from conditions three decades ago.

In 2013, high runoff was observed in December at SE04 Gårdsjön and SE15 Kindla due to high precipitation and warm weather. Annual runoff 2013, made up 40–88% of the annual precipitation, which is comparable to the 40–60% found during previous years. A higher proportion was found at the northern site Gammtratten (SE16), where a rather high snowmelt flood provided high discharge together with a runoff peak in early autumn. In the north, cold climate yields low evapotranspiration (12%) and consequently provided high runoff (Table 2). At site Aneboda (SE14), the storm-felling and bark beetle attacks have reduced the forest canopy cover and thereby followed low interception but total evapotranspiration was anyhow fairly high.

Table 2. Compilation of the 2013 water balances for the four Swedish IM sites. P–Precipitation, TF–Throughfall, I–Interception, R–Water runoff.

	Gårdsjön SE04		Aneboda SE14		Kindla SE15		Gammtratten SE16	
	mm	% of P	mm	% of P	mm	% of P	mm	% of P
Bulk precipitation, P	966	100	528	100	874	100	614	100
Throughfall, TF	707	73	538	102	468	54	591	96
Interception, P-TF	259	27	-10	<0	407	47	23	4
Runoff, R	590	61	212	40	435	50	542	88
P-R	376	39	316	60	439	50	72	12

Water chemistry in 2013

Low ion concentrations in bulk deposition and throughfall characterise the three inland sites (electrolytical conductivity = 1–2 mS m^{-1}), while sea salt provides higher ionic strength at the west coast SE04 site (5.6 mS m^{-1}, throughfall). Water pathways through the catchment soils are fairly short and shallow, providing rapid surface water formation from infiltration to surface water runoff. The acidity in deposition was similar at all sites with somewhat higher pH (0–0.1 units) in throughfall (TF) compared with bulk deposition (BD). The Gårdsjön site SE04 deviated from this pattern and pH in TF was 0.1 units lower compared to BD. As in previous years, pH was slightly higher than 5.0 in BD at most sites in 2013 (Table 3).

Table 3. Deposition chemistry 2013 at the four Swedish IM sites. S and N in kg ha^{-1} yr^{-1}.

	SE04	SE14	SE15	SE16
pH, bulk deposition	5.4	5.2	5.1	5.1
pH, throughfall	5.3	5.4	5.1	5.2
SO_4-S, bulk deposition	3.5	1.9	1.8	1.1
N-tot, bulk deposition	8.5	6.3	4.3	2.5

During the water passage through the catchment soils, organic acids are added and leached to the stream runoff, buffering at a pH between 4.5–4.8 at the three southern sites. At SE14, pH in stream water was 4.7 compared with 5.2 in bulk deposition. In the stream, ANC was approximately 0.07 meq L^{-1} as a consequence of high concentrations of DOC (≈22 mg L^{-1}). This could be compared with SE15 with an ANC of 0.01 meq L^{-1} mainly coupled to low DOC concentrations (≈10 mg L^{-1}). At the northern site SE16, ANC (≈0.1 meq L^{-1}) was to a large extent related to bicarbonate alkalinity, buffering the stream water at a pH of ca 5.6.

During the period 1996 to 2010, sulphur deposition decreased by 2–7 kg S ha^{-1} yr^{-1} and pH increased with 0.3–0.5 pH-units except for the northernmost site Gammtratten with small changes in pH. For all four sites, outflow of S was 2–3 times higher compared to deposition.

Besides ANC and pH, the stream water chemistry is to a considerable extent influenced by organic matter. At Aneboda site (SE14), the DOC concentration was high with 22 mg L^{-1} while the other sites Gårdsjön (SE04), Kindla (SE15) and Gammtratten (SE16) showed lower DOC values 15, 10 and 9 mg L^{-1}, respectively. High DOC concentrations create prerequisites for metal complexion and transport as well as high organic nitrogen fluxes. The organic nitrogen concentrations in stream water ranged from 0.19 to 0.52 mg N L^{-1}. In nitrogen budgets for catchments, transformation of inorganic nitrogen in deposition to surface runoff organic nitrogen needs consideration. At site Aneboda, the inorganic nitrogen was 0.30 mg N L^{-1}, which was high compared with the other sites where the concentrations were below 0.05 mg N L^{-1}. The high inorganic nitrogen concentrations at Aneboda are related to the forest die back.

Aluminum, toxic to fish and other gill breathing organisms in the inorganic form, has been analyzed in soil solution, groundwater and surface waters at the IM sites. Rather high concentrations occurred in the soil solution (0.2–1.4 mg L^{-1}) as well as in stream water (0.5–0.6 mg L^{-1}) at the three southern sites with low pH (4.5–4.8). At the northern site SE16 with a pH of 5.6, the aluminum concentrations were comparably low approximately 0.2 mg L^{-1}. Inorganic Al (Al_i) made up 19–43% at the four sites, corresponding to 0.12–0.24 mg Al_i L^{-1} at the three southern sites with low pH and 0.04 mg Al_i L^{-1} at the northern site Gammtratten. Those levels are considered extremely high at the three southern sites and high in the north, according to the SEPA classification. The priority heavy metals Pb, Cd and Hg were still accumulating in the catchment soils, while the concentrations were on low levels and caused no biological effects. However, methyl mercury was still exerting hazardous concentrations for limnic life.

Highlights from the Swedish Integrated Monitoring

In the national IM report for 2015, Löfgren (2015) summarized a scientific article published in Ambio (Löfgren et al. 2014), which is referred to below.

Storm felling and bark beetle attack – effects on forest and nitrogen dynamics

In January 2005 the Swedish IM site SE14 Aneboda in southern Sweden was struck by the heavy storm Gudrun (max wind 33 m s^{-1}) and 15–20% of the trees were windthrown. Later, in 2008 bark beetle (*Ips typographus* L.) infestation occurred and most big trees were affected resulting in almost no living Norway spruce trees with a breast height diameter over 20 cm (Fig. 2) in the 2011 inventory.

The forest die-back effects on the nitrogen concentrations were local and limited in soil water and groundwater. Total nitrogen in stream water didn't change very much either and the N_{tot} leaching reached 2.1 kg ha^{-1} yr^{-1} as a mean for the period 2005–2012 compared with the mean 1.9 kg ha^{-1} yr^{-1} for the period before the storm (1997–2004). However, inorganic nitrogen, i.e. the NO_3-N and NH_4-N concentrations reached up to 0.5 mg L^{-1} and 0.1 mg L^{-1}, respectively, while being about 0.05 mg L^{-1} before the storm. Runoff in stream water increased from approximately 0.1 kg ha^{-1} yr^{-1} and 0.05 kg ha^{-1} yr^{-1}, respectively, before the storm to 0.1–1.1 kg NO_3-N ha^{-1} yr^{-1} and 0.05–0.1 kg NH_4-N ha^{-1} yr^{-1} after the event.

Figure 2. The intensive vegetation plot no 1 viewed from the northwest corner in the middle of August in 2004 (upper left), 2007 (upper right), 2010 (lower left) and 2013 (lower right). The major storm Gudrun hit the area in January 2005 and the bark beetle infestation became visible in 2008. Photo: Ulf Grandin, SLU.

Healthy forest ecosystems provide environmental services

In the Swedish national report, the importance to maintain ecosystem functions to support environmental services such as clean air, healthy soil, high water quality and food supply was addressed. To reach this, there are needs to make further efforts to mitigate air pollution, preserve biodiversity and limit climate change.

References

Löfgren, S., Grandin, U. & Stendera, S. 2014. Long-term effects on nitrogen and benthic fauna of extreme weather events: Examples from two Swedish headwater streams. Ambio 43, 58-76.

Löfgren, S. (ed.) 2015. Integrated monitoring of the environmental status in Swedish forest ecosystems – IM. Annual report for 2013. Swedish University of Agricultural Sciences. Department of Aquatic Sciences and Assessment, Report 2015:8. Uppsala Sweden. 32 pp, 22 appendices. (In Swedish with English summary)

DOCUMENTATION PAGE

<table>
<tr><td>Publisher</td><td colspan="3">Finnish Environment Institute (SYKE)</td><td>Date
August 2015</td></tr>
<tr><td>Author(s)</td><td colspan="4">Sirpa Kleemola and Martin Forsius (eds.)</td></tr>
<tr><td>Title of publication</td><td colspan="4">24th Annual Report 2015
Convention on Long-range Transboundary Air Pollution
International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems</td></tr>
<tr><td>Publication series and number</td><td colspan="4">Reports of the Finnish Environment Institute 31/2015</td></tr>
<tr><td>Theme of publication</td><td colspan="4"></td></tr>
<tr><td>Parts of publication/ other project publications</td><td colspan="4">The publication is available on the internet: www.syke.fi/publications | helda.helsinki.fi/syke</td></tr>
<tr><td>Abstract</td><td colspan="4">The Integrated Monitoring Programme (ICP IM) is part of the effect-oriented activities under the 1979 Convention on Long-range Transboundary Air Pollution, which covers the region of the United Nations Economic Commission for Europe (UNECE). The main aim of ICP IM is to provide a framework to observe and understand the complex changes occurring in natural/semi natural ecosystems.

This report summarizes the work carried out by the ICP IM Programme Centre and several collaborating institutes. The emphasis of the report is in the work done during the programme year 2014/2015 including:

• A short summary of previous data assessments
• A status report of the ICP IM activities, content of the IM database, and geographical coverage of the monitoring network
• A progress report on dynamic vegetation modelling at ICP IM sites
• A progress report on trend assessment for bulk deposition, throughfall and runoff water chemistry and climatic variables at ICP IM sites in 1990–2013
• A progress report on heavy metal trends at ICP IM sites
• National Reports on ICP IM activities are presented as annexes.</td></tr>
<tr><td>Keywords</td><td colspan="4">Integrated Monitoring, ecosystems, small catchments, air pollution, critical loads, dynamic modelling</td></tr>
<tr><td>Financier/ commissioner</td><td colspan="4">Swedish Environmental Protection Agency, Ministry of the Environment, Finland, Working Group on Effects of the LRTAP Convention</td></tr>
<tr><td rowspan="2"></td><td>ISBN
978-952-11-4524-7 (pbk.)</td><td>ISBN
978-952-11-4525-4 (PDF)</td><td>ISSN
1796-1718 (print)</td><td>ISSN
1796-1726 (online)</td></tr>
<tr><td>No. of pages
58</td><td>Language
English</td><td>Restrictions
Public</td><td>Price (incl. tax 8 %)</td></tr>
<tr><td>For sale at/ distributor</td><td colspan="4"></td></tr>
<tr><td>Financier of publication</td><td colspan="4">Finnish Environment Institute (SYKE)
P. O.Box 140, FI-00251 Helsinki, Finland
Tel. +358 20 610 123, Email: neuvonta.syke@ymparisto.fi</td></tr>
<tr><td>Printing place and year</td><td colspan="4">Juvenes Print, Tampere 2015</td></tr>
</table>

KUVAILULEHTI

Julkaisija	Suomen ympäristökeskus (SYKE)	*Julkaisuaika* Elokuu 2015
Tekijä(t)	Sirpa Kleemola ja Martin Forsius (toim.)	
Julkaisun nimi	**24th Annual Report 2015** Convention on Long-range Transboundary Air Pollution International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems	
Julkaisusarjan nimi ja numero	Suomen ympäristökeskuksen raportteja 31/2015	
Julkaisun teema		
Julkaisun osat/ muut saman projektin tuottamat julkaisut	Julkaisu on saatavana internetistä: www.syke.fi/julkaisut | helda.helsinki.fi/syke	
Tiivistelmä	Yhdennetyn seurannan ohjelma (ICP IM) kuuluu kansainvälisen ilman epäpuhtauksien kaukokulkeutumista koskevan yleissopimuksen "Convention on Long-range Transboundary Air Pollution" (1979) alaisiin seurantaohjelmiin. Yhdennetyn seurannan ohjelmassa selvitetään kaukokulkeutuvien saasteiden ja muiden ympäristömuutosten vaikutuksia elinympäristöömme. Muutosten seurantaa ja ennusteita muutosten laajuudesta ja nopeudesta tehdään yleensä pienillä metsäisillä valuma-alueilla, mutta verkostoon kuuluu myös muita alueita. Tämä julkaisu on kooste ohjelmakeskuksen ja yhteistyölaitosten toiminnasta kaudella 2014/2015, joka sisältää: - Lyhyen yhteenvedon ohjelmassa aiemmin tehdyistä arvioinneista - Kuvauksen ICP IM ohjelman toiminnasta ja ohjelman seurantaverkosta - Tiivistelmät toiminnasta ohjelman prioriteetti aihealueilla: • dynaaminen kasvillisuus- ja maaperämallinnus ICP IM alueilla • trenditarkastelut ICP IM alueiden laskeuma- ja valuntadatoille • raskasmetallitrendit ICP IM alueilla - Kuvauksia kansallisesta ICP IM toiminnasta eri maissa liitteenä	
Asiasanat	Yhdennetty ympäristön seuranta, ekosysteemit, pienet valuma-alueet, ilmansaasteet, kriittinen kuormitus, dynaamiset mallit	
Rahoittaja/ toimeksiantaja	Naturvårdsverket (Ruotsi), Ympäristöministeriö, Kaukokulkeutumissopimuksen vaikutustyöryhmä	

	ISBN 978-952-11-4524-7 (nid.)	ISBN 978-952-11-4525-4 (PDF)	ISSN 1796-1718 (pain.)	ISSN 1796-1726 (verkkoj.)
	Sivuja 58	*Kieli* englanti	*Luottamuksellisuus* julkinen	*Hinta (sis. alv 8 %)*
Julkaisun myynti/ jakaja				
Julkaisun kustantaja	Suomen ympäristökeskus (SYKE) PL 140, 00251 Helsinki Puh. 020 610 123, Sähköposti: neuvonta.syke@ymparisto.fi			
Painopaikka ja -aika	Juvenes Print, Tampere 2015			

PRESENTATIONSBLAD

Utgivare	Finlands miljöcentral (SYKE)		*Datum* August 2015
Författare	Sirpa Kleemola och Martin Forsius (red.)		
Publikationens titel	**24th Annual Report 2015** Convention on Long-range Transboundary Air Pollution International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems		
Publikationsserie och nummer	Finlands miljöcentrals rapporter 31 /2015		
Publikationens tema			
Publikationens delar/ andra publikationer inom samma projekt	Publikationen finns tillgänglig bara på internet: www.syke.fi/publikationer | helda.helsinki.fi/syke		
Sammandrag	Programmet för Integrerad övervakning av miljötillståndet (ICP IM) är en del av monitoringstrategin under UNECE:s luftvårdskonvention (LRTAP). Syftet med ICP IM är att utvärdera komplexa miljöförändringar på avrinningsområden. Rapporten sammanfattar de utvärderingar som gjorts av ICP IM Programme Centre och de samarbetande instituten under programåret 2014/2015. Rapporten innehåller: - En sammanfattning av programmets nuvarande omfattning och databasens innehåll - En syntes av tidigare utvärderingar av data från programmet - Sammanfattning beträffande utvärderingar inom följande sektorer: • modellering av markkemi och markflora • trendanalys av ICP IM depositions- och avrinningsdata • trendanalys av ICP IM tungmetall data - Beskrivning av nationella ICP IM aktiviteter		
Nyckelord	Integrerad miljööervakning, ekosystem, små avrinningsområden, luftföroreningar, kritisk belasting, dynamiska modeller		
Finansiär/ uppdragsgivare	Naturvårdsverket (Sverige), Miljöministeriet, Working Group on Effects of the LRTAP Convention		

	ISBN 978-952-11-4524-7 (hft.)	ISBN 978-952-11-4525-4 (PDF)	ISSN 1796-1718 (print)	ISSN 1796-1726 (online)
	Sidantal 58	*Språk* engelska	*Offentlighet* Offentlig	*Pris (inneh. moms 8 %)*
Beställningar/ distribution				
Förläggare	Finlands miljöcentral (SYKE) PB 140, 00251 Helsingfors Tfn. +358 20 610 123, Email: neuvonta.syke@ymparisto.fi			
Tryckeri/tryckningsort -år	Juvenes Print, Tammerfors 2015			

The Integrated Monitoring Programme (ICP IM) is part of the effect-oriented activities under the 1979 Convention on Long-range Transboundary Air Pollution, which covers the region of the United Nations Economic Commission for Europe (UNECE). The main aim of ICP IM is to provide a framework to observe and understand the complex changes occurring in natural/semi natural ecosystems.

This report summarizes the work carried out by the ICP IM Programme Centre and several collaborating institutes. The emphasis of the report is in the work done during the programme year 2014/2015 including:

- A short summary of previous data assessments
- A status report of the ICP IM activities, content of the IM database, and geographical coverage of the monitoring network
- A progress report on dynamic vegetation modelling at ICP IM sites
- A progress report on trend assessment for bulk deposition, throughfall and runoff water chemistry and climatic variables at ICP IM sites in 1990–2013
- A progress report on heavy metal trends at ICP IM sites
- National Reports on ICP IM activities are presented as annexes.

24TH ANNUAL REPORT 2015

SYKE

LRTAP
Long-range Transboundary Air Pollution

ISBN 978-952-11-4524-7 (pbk.)
ISBN 978-952-11-4525-4 (PDF)
ISSN 1796-1718 (print)
ISSN 1796-1726 (online)

FINNISH ENVIRONMENT INSTITUTE